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Representing and Processing Video Information in Computer Vision Systems

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[Article by D. A. Denisov, A. K. Dudkin, and M. V. Plaksin, Leningrad; first paragraph is IZVESTIYA AKADEMII NAUK SSSR: TEKHNICHESKAYA KIBERNETIKA introduction]

[Text] This article gives the content characteristics of computer vision tasks. The iconic, segmented, geometric, and relational levels of representing video information are examined. Those processing tasks and processes that are characteristic of each representation level are analyzed. The concept of a control strategy for video information transformation processes in computer vision systems is discussed, and the fundamental mechanisms of organizing computer processes are examined. The most urgent research directions are presented.

Introduction. As a scientific discipline, computer vision is currently in its formative period. Despite the fact that the first monograph collections on this theme came to light about a decade ago it is hardly possible to state that all of the aspects of this complex topic are now clear.[1,2]

The problem is that computer vision encompasses problems and solution methods from a whole series of scientific directions, the most important of which are the following: the psychophysical problems of visual perception, digital processing and image analysis, the architecture of the respective expert systems and the technology for developing them, and engineering knowledge. Each of the these directions is an independent research area that uses its own problem-solving methodology and its own classes of methods and algorithms. This nonuniformity of the makeup of the problems that must be solved and their multifaceted nature, complexity, and urgency for a broad spectrum of applications make the problem of computer vision a "hot spot" of scientific pursuit.

The purpose of the present review is to examine publications on the problem from several positions. Above all the authors would like to provide a detailed examination of two fundamental concepts of computer vision:

the hierarchy of representations of video information in computer vision systems and the related hierarchy of tasks and methods of processing this information;

strategies for controlling video information transformation processes.

It is suggested that the aforementioned topics be analyzed with an accent on the mathematical and algorithmic aspects of accomplishing the most frequent subtasks in order to give a more specific nature to both the subtasks themselves and the methods used to solve them. It is thought that this will encounter support from algorithm analysts[1-8] and specialists in the field of developing problem-oriented program systems. Finally, the authors have primarily concentrated their attention on the so-called two-dimensional tasks of computer vision[9,10] in view of their fundamental nature and the fact that they are the least discussed in the domestic literature. A recently published work[1] was devoted to problems of the three-dimensional tasks of computer vision.

1. The task of computer vision. In the final analysis, the goal of virtually all computer vision tasks is to clarify the following: WHAT is depicted on a picture (i.e., what kinds of objects are located in the observer's field of view?); WHERE are these objects located (i.e., what are their spatial and temporal attributes?); and WHY are the objects located in the field of view in such a combination (i.e., what kind of situation overall is being observed?).[5] These end goals of the visual process include a broad spectrum of subtasks, beginning with so-called "early" processing (coding, restoring, improving the quality, segmenting) and ending with the subtasks of "late" processing (plotting relational descriptions of scenes, synthesizing processes of comparing relational structures).

The tasks of computer vision extend beyond the framework of image recognition tasks. Only a few of them can be successfully described by the classical scheme of recognition, where a final classification alphabet and a rather simple model of the description of the classified object (image) are specified and a decision rule relating the image to one of the prespecified classes is found.[9,10] Much more frequently, research encounters a situation where designating the final classification alphabet is difficult, establishing the specified model of an image once and for all is problematic, and synthesizing a decision rule in the sense presented above is impossible. The task of recognition is, in this case, transformed into the task of coming to know objects and constructing an overall description of the depicted situation in its entirety.

The dominant methodological approach to accomplishing the tasks of computer vision is the approach based on using knowledge.[2-12] Most researchers today are clearly aware of the fact that performing the integrated and complicated tasks entailed in understanding images is impossible if, at each specific moment in time, they have only digital arrays of N x N points (which are a digital representation of some image) at their disposal. Accomplishing these tasks requires the presence in memory of a system of diverse information:

1) information about the modes of observing the image (the physical characteristics of the sensor, the time and location of the observation, the approach aspect, etc.);

2) information about the characteristics of the propagation medium (the transmission signal) of the video signal;

3) information about the subject area (possible types of objects and their brightness, color, and geometric properties); and

4) information about the preceding experience in processing this class of image (information about the most effective algorithms, their parameters, and the conditions of their use). All this diverse information constitutes the knowledge base of computer vision systems, to which the latter should provide convenient and quick access.[2-12]

Implementation of the aforementioned methodological approach is based on the concept of a hierarchical method of representing and processing information.[3-6] "If visual perception is considered a process of compiling information at the inlet to a computer vision system from models and concepts that existed previously in the system, it should then be acknowledged that there is an enormous descriptive gap between the input image and modes that describe or abstract the information contained in it.[3] This motivation also explains the fact that it is possible to distinguish four categories of representations generating a hierarchy of processing processes[3-6,9,10] to surmount the aforementioned gap The levels of the representation of video information and the processes of processing it are examined in detail in the next section.

2. Levels of representation and processes of processing video information. Four levels of representing video information in a computer vision system may be distinguished: iconic, segmented, geometric, and relational.[2,5]

Iconic representations of images. Iconic representations are representations of images in the conventional visual form that is convenient for human perception. Besides natural images of physical processes, phenomena, and situations, which are generally recorded in a plane recording medium (photographic and movie film, photographic paper, x-ray film, a CRT screen), this category also includes intrinsic images. These include a monochromatic field isolated from a polychromatic field, a gradient field, distribution of the depth coefficient along the plane of an image, or an analogous distribution of another physical parameter.[3,4,12] The results of discrete orthogonal transforms of images may be represented in iconic form. In this case the term pseudoimage is used.

The tasks and processes of processing on this level fully encompass the sphere of research that is termed digital image processing in the literature.[13-16] In the overwhelming majority of cases, these tasks are reduced to restoring the image, i.e., removing their amplitude and geometric distortions and improving the quality of their visual perception. It is important to emphasize that here an image in iconic form is again the result of the processing.

The processes of processing iconic video information are based on geometric and amplitude transformations of images. In the first case this refers to the transformation of coordinates, and in the second case it refers to the transformation of a scale of brightness values.[13-16] The methodological and algorithmic problems entailed in implementing these processes have been developed and researched in detail. The following may be listed as the principal classes of processing algorithms[13-16]:

1) flow algorithms of the linear transformation of a brightness scale;

2) spatially local algorithms of algorithm transformations based on implementation of a two-dimensional discrete convolution;

3) recursive and nonrecursive algorithms for filtration in spatial and frequency regions;

4) algorithms for histogram transformations;

5) fast algorithms for discrete orthogonal transformations and others.

On this level of representation images are generally described by the model of a random field relative to whose properties and parameters assumptions are made. This type of model determines the typical processing methodology, which is based on the theory of random functions and fields, information theory, signal theory, and the theory of discrete orthogonal transformations.[13,17,18]

It should also be stated that these processes of processing iconic video information permit parallel computations. This is why special computer architecture is actively used to implement them.[19-21]

Segmented representations of images. Segmented representations of images (or simply image segmentation) are formed from iconic representations by isolating the boundaries of like regions or by marking the internal points of these regions.[22,23] The main task of this level is thus to isolate connected regions of an image that are alike with respect to brightness, color, or textural properties.

Isolating boundaries and marking are the dominant processes of processing and are based on alternative approaches to solving the problem.[22] In the first case the solution is based on the discontinuity of the properties of the points of the image upon a transition from one region to another, and in the second case it is based on the proximity of the local properties of points within the region. The task of segmenting images lends itself to exact mathematical formulation.[4,22]

Figure 1 illustrates the main classes of methods and algorithms for accomplishing the task within the framework of the approaches that have been formulated.

The process of marking regions has as its foundation both traditional methods of statistical data processing (parametric and nonparametric clustering procedures) and comparatively new approaches to transforming visual information (merge and divide algorithms based on pyramids and square trees, algorithms for relaxation marking). As far as isolating the boundaries of regions is concerned, the dominant methodological direction is spatial differentiation, which is reduced to formulation

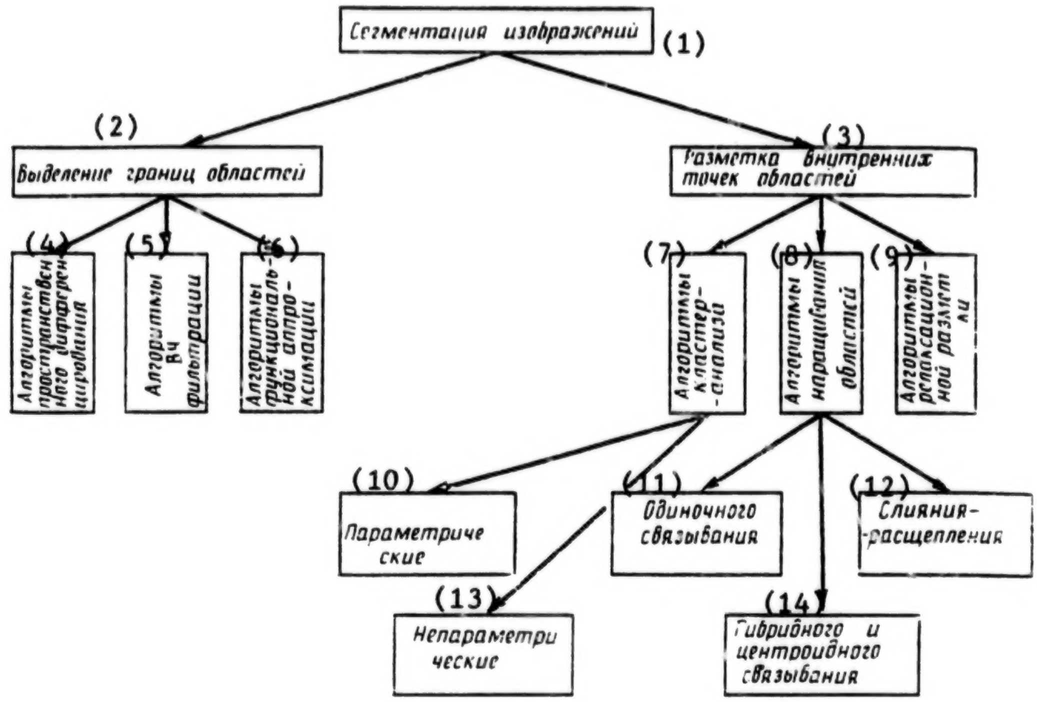

Figure 1.

Key: 1. Segmentation of images 2. Isolation of images' boundaries 3. Marking internal points of regions 4. Algorithms for spatial differentiation 5. Algorithms for high-frequency filtration 6. Algorithms for functional approximation 7. Algorithms for cluster analysis 8. Algorithms for building up regions 9. Algorithms for relaxation marking 10. Parametric 11. Single linking 12. Merging-dividing 13. Nonparametric 14. Hybrid and centroid linking

of a gradient field and its subsequent threshold processing. A significant number of works have been published on the problems of image segmentation. Review articles[22,23] give a detailed examination of this problem.

At the same time it should be noted that the approaches to and methods of formulating segmented images have a number of limitations. The main limitation is apparently the fact that the regions isolated in an image correspond to the regions of real objects. The fact that the latter have shadows, highlights, and the effect of uneven absorption and/or reflection of light makes it impossible to consider them identical to like regions in the sense of a likeness predicate. At the same time, segmented images are convenient source information for isolating the semantic objects of a scene.

The limitations of methods of isolating the boundaries of regions are connected not so much with the contour method of representing the results of segmentation as with the need to perform rather artful postprocessing to eliminate breaks, false contour points in the contours, thin contours, etc.

In the sense of computer expenditures it is preferable when following this approach to use spatial differentiation algorithms that, in a number of cases, can be reduced to a two-dimensional convolution with special kernels. The latter fact makes it possible to implement them in a computer environment that permits parallel computations (matrix processors, multiprocessor systems).

There are a number of reasons for the limitations of methods of marking regions. For some reason or other, the likeness predicate LP[22] in each of these algorithms is specified implicitly. Accomplishing the task successfully depends on how the likeness of the regions in the sense of their mental and visual perception coincides with the likeness specified by the likeness predicate LP. It should be acknowledged that such a coincidence for real images is more likely the exception rather than the rule. Obtaining it entails laborious experimental adjustment of the parameters of the segmentation algorithm.

Algorithms for a cluster analysis and to build up regions are alternatives to one another in a certain sense, i.e., in the first case the marking is based mainly on a consideration of the image's global amplitude properties while in the second case it is based primarily on a consideration of local spatial information. That is why cluster analysis algorithms most often yield regions without sufficiently smooth boundaries that contain holes and "salt-and-pepper"-type noise. On the other hand algorithms to build up regions introduce methodological errors into the shape of the boundaries (in the case of merge-and-divide algorithms) and are also incorrect

during the marking of U-shaped regions (in the case of centroidal linking algorithms). A combined method of spatial clustering was proposed to integrate the positive properties of both methodological directions.

In algorithms of this type, when the points of an image are grouped and clusters are formed, an allowance is made for the proximity of the respective vectors in the space of the characteristic attributes as well as for the proximity (adjacency) of the points on a plane. A discussion of a number of specific spatial clustering algorithms may be found elsewhere.[23]

Finally, yet another limitation of the algorithms under discussion is that their computer implementation is very labor intensive from a computing standpoint. The labor intensity here is related to the multiple iterative processing of ultralong samples by using parametric cluster analysis algorithms and algorithms for relaxation marking with additional expenditures of computer time and memory when processing hierarchical structures (pyramids, square trees) by using merge and divide algorithms. Constructing segmentation algorithms that are efficient with respect to speed and quality of the results they produce is thus an urgent task. A fast algorithm for cluster analysis of images that combines the advantages of the parametric and nonparametric approaches to constructing clustering procedures has been proposed.[24,25]

The geometric structures level. The geometric structures of images are the next level in the hierarchy of representing video information. The concept "geometric structure" combines the set of geometric properties contained in an images of objects/regions.[26] There are two approaches to constructing the description of geometric structures: attributive and structural.[3,4,26,27]

Attributive descriptions give information about the geometric properties of regions in the form of a set of topological, metric, and parametric attributes specifying the connectivity, size, location, orientation, and shape of an object as a whole and the attributes of the shape of its boundaries. Structural descriptions assume the decomposition of an object/region into certain components—primitives characterizing both the specific fundamental properties of the shape of the region itself and the shape of its boundaries as well as its topology, dimensions, etc. Here the differences between the geometric properties of regions are concentrated not only in the different primitives used but also in their interrelationship. The structural approach thus reflects the mechanism of the formation of the visual image of one individual region or another and the entire image as a whole.

Figure 2 classifies the approaches, methods, and main classes of algorithms for constructing descriptions of geometric structures.

The main processing tasks on this level are as follows:

—the task of calculating the set of the regions'/objects' topologic, metric, and parametric attributes;

—the task of decomposing a region and its boundaries into very simple primitives/components;

—the task of synthesizing a structural description for a region/object. The processing processes to accomplish these tasks constitute the procedural filling of the given level of the hierarchy of representing video information.

A comparatively new region of research, which has received the name descriptive geometry in the literature,[26,28-39] is the theoretical basis of the attributive approach to description. Discrete analogues of such fundamental geometric properties of regions in a plane as connectivity, convexity, concavity, curvature, etc., are formulated within the framework of this discipline. Table 1 presents a set of attributes to describe the geometric properties of regions of discrete images required when constructing attributive descriptions and provides the necessary explanations.

Table 1

	Described Property of Object	Category of Attribute (Attributes)	Attribute (Attributes) and Its Semantic Content
1	2	3	4
1	Connectivity	Topological	NC, no. connections, components
			NH, no. holes
			NE, Euler number
2	Size	Metric	NS, section
			NP, perimeter
			a, b, sides of the rectangle described
			d_1, d_2, diameter and width of the object
			d_1', d_2', orthogonal chords
3	Shape of object	Metric	T, thickness ratio (thickness)
			E, compactness

Table 1 (Continued)

	Described Property of Object	Category of Attribute (Attributes)	Attribute (Attributes) and Its Semantic Content
			CNV, convexity
			A, aspect ratio
4	Location of object	Metric	i_0, j_0, coordinates of gravity center
5	Orientation of object	Metric	, angle between figure's main inertia axis and x axis
6	Shape of object's boundaries	Parametric	Cc, chain code
			Rc, "rupture" chain code
			$\xi_r = f_1(s)$, $\xi_\varphi = f_2(s)$, Freeman contours
			$\psi = f_3(s)$, "psi-ess" curve
			$S_{FR}(\omega) = FR[k(s)]$, Fourier descriptor
			$P_t(x) = c_0 + c_1t + ... + c_tx^t$, approximating polynomial

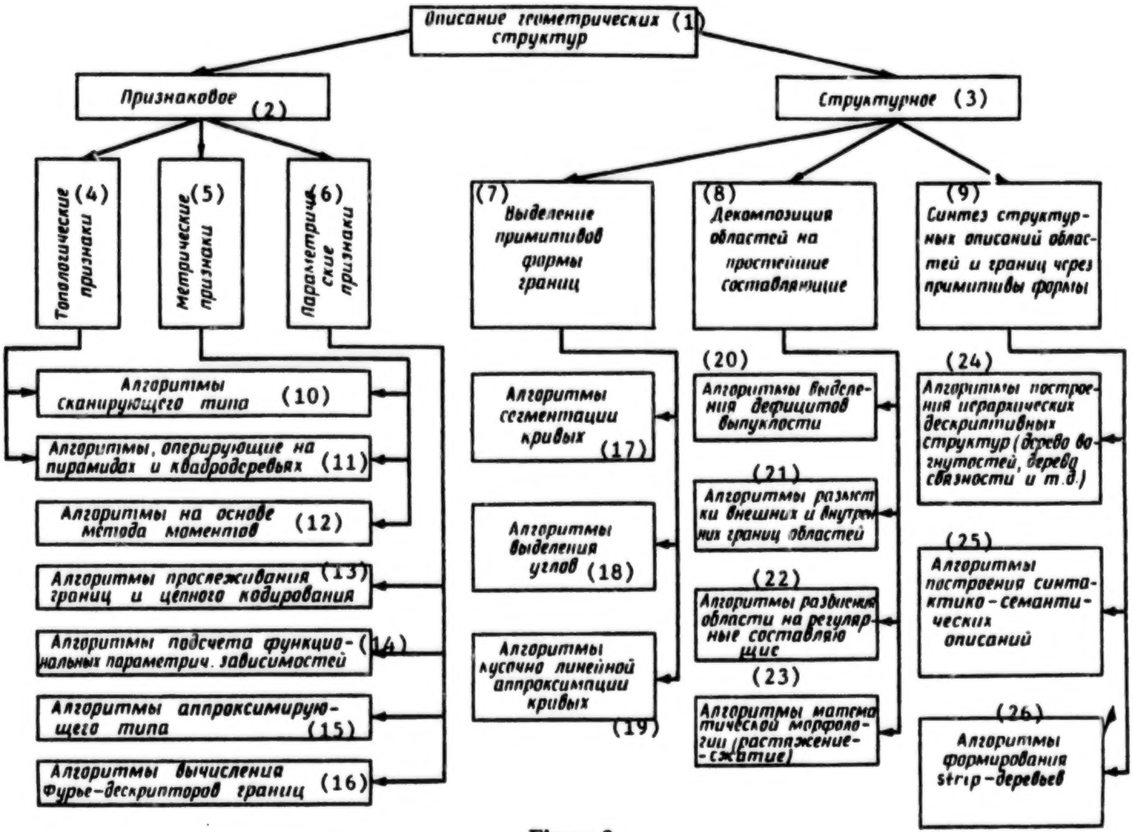

Figure 2.

Key: 1. Description of geometric structures 2. Attributive 3. Structural 4. Topologic attributes 5. Metric attributes 6. Parametric attributes 7. Isolating primitives of shape of boundaries 8. Decomposing regions into simplest components 9. Synthesis of structural descriptions of regions and boundaries through the primitives of the shape 10. Scanning-type algorithms 11. Algorithms based on pyramids and square trees 12. Algorithms based on the method of moments 13. Algorithms for tracking boundaries and chain coding 14. Algorithms to calculate the functional parameters of dependencies 15. Approximation-type algorithms 16. Algorithms to calculate Fourier-descriptor boundaries 17. Curve segmentation algorithms 18. Algorithms to divide angles 19. Algorithms for piecewise-linear approximation of curves 20. Algorithms to isolate convexity deficits 21. Algorithms to mark the external and internal boundaries of regions 22. Algorithms to subdivide a region into regular components 23. Mathematical morphology (extension-compression) algorithms 24. Algorithms to construct hierarchical descriptive structures (a concavity tree, a connectivity tree, etc.) 25. Algorithms to construct syntacticosemantic descriptions 26. Algorithms to form strip trees

The attributes presented in Table 1 are determined by the following relationships.

1) NE = NC - NH. 2) NS = [DB] (the number of elements of the set DB), NP = [DE] (the number of elements in the set of boundary points DE), $a = i_2 - i_1$, where i_1 and i_2 are the minimum and maximum coordinates of the object along the x axis; $b = j_2 - j_1$, where j_1 and j_2 are the minimum and maximum coordinates of the object along the y axis; d_1 and d_2 are the maximum and minimum distances between the outer parallel tangents to the object (Fere [transliteration] diameters with arbitrary slopes), d_1' and d_2' are the maximum and minimum orthogonal chords, $d_1' = \max[\rho(de_1, de_2)]$ (de being an element of the set DE), $d_2' = \max[\rho(de_1, de_2)]f[de_1, de_2][d<]_1'$ (de being an element of the set DE).

3) $T = 4\pi(NS/NP^2)$; $E = NP^2/NS$. CNV = 1 if the object is convex and 0 if the object is nonconvex; $A = \lambda_1/\lambda_2$, where λ_1 and λ_2 are, respectively, the maximum and minimum eigenvalues of the scattering matrix of the object (set DB).

$$i_0 = m_{10}/m_{00} = \Big[\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} if(i,j)\Big] \Big/ \Big[\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} f(i,j)\Big],$$

$$j_0 = m_{01}/m_{00} = \Big[\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} jf(i,j)\Big] \Big/ \Big[\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} f(i,j)\Big].$$

where f(i, j) is the characteristic function of the object, f(i, j) = 1 if the point (i, j) belongs to the object and 0 if the opposite case; m_{pq} are the initial moments of the order p + q; and is the direction of the eigenvector of the scattering matrix C_1 corresponding to the maximum eigenvalue.

$\xi_r = f_1(s) = r/r_{max}$, where r is the object's radius vector, which connects the point (i_0, j_0) with some boundary point, and r_{max} is the maximum (with respect to length) radius vector

$$\xi_\varphi = f_2(s) = \Delta\varphi,$$

where φ is the turning angle of the object's radius vector, s is the arc length, and $\psi = f_3(s)$ is the change in the slope of the tangent ψ to the axis of the abscissas as a function of the arc length s.

The limited number of publications does not permit pausing for a detailed analysis of classes of algorithms to work out attributive descriptions. A discussion of these topics may be found in a review[26] containing a rather complete bibliography on this theme.

The structural approach to describing the geometric properties of regions is frequently identified with the syntactic branch of this methodological direction thanks to the fundamental works of K. S. Fu.[40-42] Here primitives are characters of the alphabet of some formal language of a grammar. The substitution rules of this language's grammar indicate compositional relationships between primitives. The input image may thus be interpreted as a line of the language that has been generated by some grammar representing some class of shape. A selection tree may be used for purposes of structural description of the shape of an object (image).[15,40-42,46]

Two directions may be identified within the framework of a syntactic description of shape. The first directly transfers the results of the classical theory of formal grammars and languages to the problem of describing shape. Here images are described by line (one-dimensional) grammars).[40,46] At the same time, one-dimensional concatenation is too strong a constraint on using syntactic methods. Therefore syntactic methods based on using grammars with a greater dimensionality, i.e., grammars of networks, tables, graphs, and trees,[15,40-42] have recently been developed. This direction does not, however, use semantic information about the image during the process of description in explicit form. The desire to make a structural description more flexible and efficient led to the use of attributive grammars that consider the semantic context of an image in explicit form. The syntacticosemantic direction, which is based on syntactic methods and which makes significant use of the semantic aspect of an image, was thus carved out.[42-45]

Another branch of the structural approach is based on a rejection of formalism borrowed from the theory of formal grammars and languages. Here the structural model (relational structure) is constructed on the basis of a consideration of the diverse relationships between the primitives of the regions and boundaries in the form of tables, trees, and common types of graphs, etc. For example, the relationships "follows after" and "to the left of" are frequently used to describe an object's boundaries, and the relationships "whole-part" and "inside of" are used to describe regions/relationships. The latter two relationships lie at the basis of the construction of such descriptive structures as a "concavity tree" and "connectivity tree."[3,27] Figures 3 and 4 illustrate these structures.

Structural description methods may be divided into methods of describing boundaries and methods of describing regions.[27] Within the framework of this type of division syntactic descriptions dominate in the first case, and relational descriptions dominate in the second.

An attribute that is of no small importance to any description is its informativeness. If the informativeness of a description is understood in the sense discussed elsewhere,[46] i.e., if it is assumed that the description D_1 is more informative than is the description D_2, when and only when the set of objects satisfying D_1 is contained in the set of objects satisfying D_2, the informativity of the attributive descriptions increases upon a transition from topological attributes to metric or from metric to parametric descriptions of the boundaries. The approach and

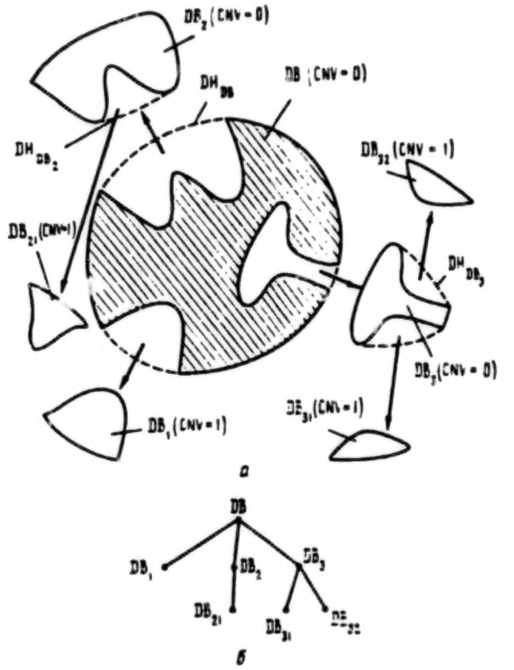

Рис. 3

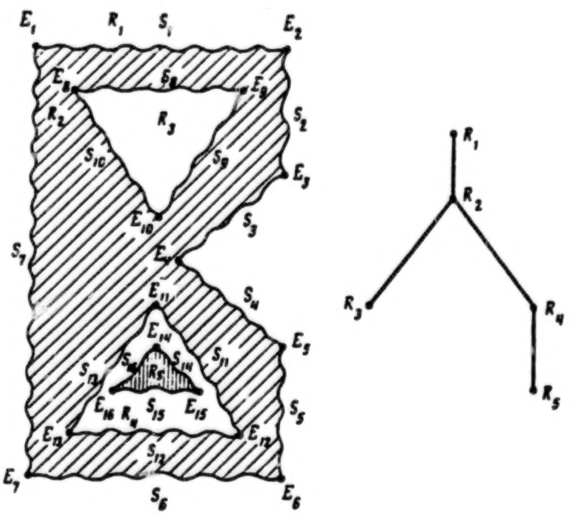

Рис. 4

Figures 3 and 4

specific class of algorithms to construct a description of geometric structures should be selected with an allowance for the methods and algorithms used in the early stages of analysis. If, for example, the segmentation was performed by isolating the boundaries of objects, it is advisable to use parametric attributive descriptions or structural syntactic descriptions of the shapes of the boundaries. At the same time, for the case where segmentation was performed by marking regions, it is likely more convenient to use attributive descriptions with the help of categories of topologic and metric attributes or else structural relational descriptions of the shapes of boundaries (for example, descriptive hierarchical structures). Using segmentation of pyramids and square trees in this stage makes it possible to render the process of segmentation and calculation of metric attributes continuous. What has been said underscores the interconnection of the representation levels and the processing processes not only from a conceptual standpoint but also from the standpoint of their algorithmic and program implementation.

Despite the fact that they appear to be alternatives, the approaches to describing geometric structures are mutually complementary. For example, the components of an image termed "convexity deficits" are identified when a "concavity tree" is used. The terminal vertices of a "concavity tree" yield convex subportions of an object, the description of which may be individualized by a set of metric attributes.

The level of relational structures. Relational representations of video information should yield those forms of description that would make it possible to perform the task of recognizing objects and interpreting images. Striving to make the most complete allowance possible for the diversity of the relationship between both the individual parts of objects and between objects themselves lies at the foundation of relational structures (models) of images. These relationships may be unary and thus point to some property of an object, for example, to its color (the sky is light blue, the grass is green), or it may be binary and point, for example, to a spatial relationship ("to the left of", "under," "over," etc.), or it may have a higher dimensionality.[47-49] The structural descriptions of the geometric properties of regions that were examined in the previous subsection are the simplest form of relational models.[3,4,47-52] In fact, as has already been mentioned, the relationships "inside of" and "part-whole" lie at the basis of connectivity and concavity trees. The spatial location of objects in an image may be described by a common type of graph that also belongs to the class of relational models. Examples of such graphs are RSE-graphs and RAG-graphs,[47,48] which yield information about the relative location of regions, sections of boundaries, and points of a break in these boundaries and information about the adjacency of regions. Figure 5 illustrates these relational models.

The following ternary relationship may be used for the characteristic of the relative location of the regions and boundaries[47,48]:

$$RR_3 = \text{unordered set: } DE_i, S_1, S_2,$$

where DE_i is the i-th section of the boundary, S_1 is the region to the left of the section of the boundary, and S_2 is the region to the right of the section of the boundary. There are a great number of relationships similar to that presented above.[3,4,15,47-52]

In a number of cases the graphs characterizing the relative location of objects may be weighted. For

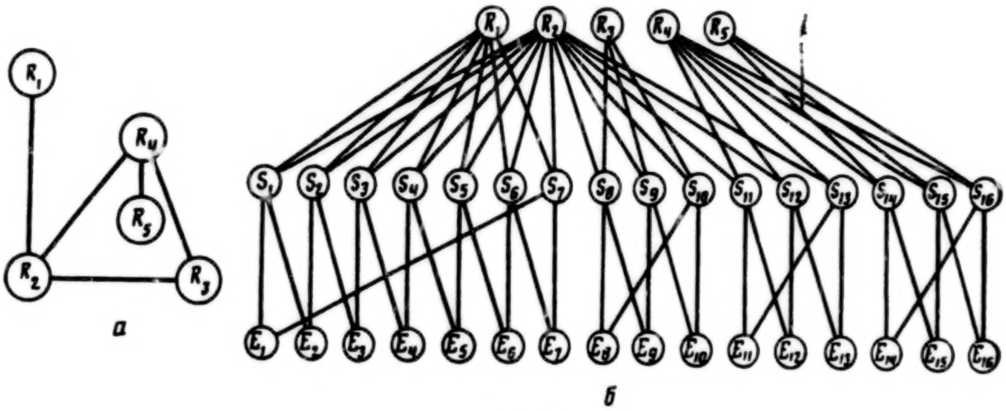

Рис. 5

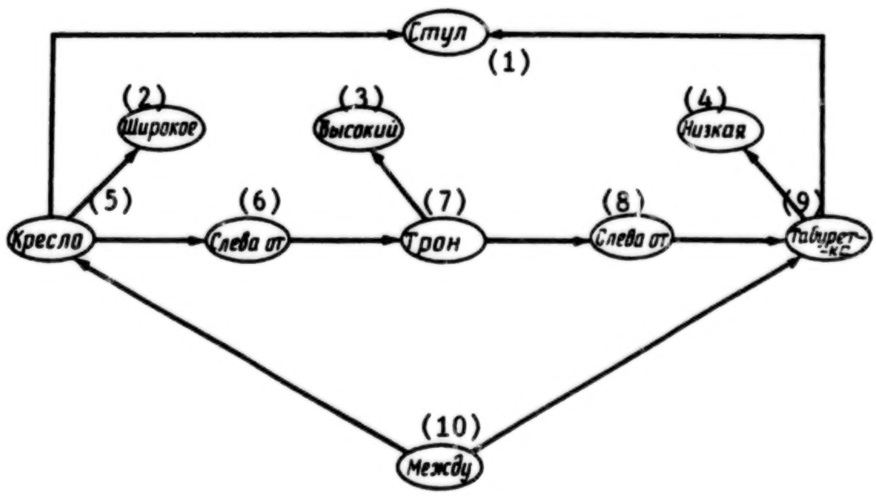

Рис. 6

Figures 5 and 6

Key: 1. Chair 2. Wide 3. High 4. Low 5. Armchair 6. To the left of 7. Throne 8. To the left of 9. Small stool 10. Between

example, the distance between the gravity centers of the regions under examination may serve as a weight of the relationship. A simple computer representation permits a similar type of graph.[15] The main sphere of application of the aforementioned types of relational models is in the description of local-spatial information of an image. That is why they are used extensively in the task of describing geometric structures. This is also the case because a graph naturally reflects the plane structure of a scene (object) and permits a wide set of processing methods.[4,6,15,40-45] At the same time these modes possess a significant limitation related to the likeness of the semantic information described. This likeness is the result of the consideration of some one type of connection between objects (parts of objects): generic, cause and effect, spatial, role, etc.

The strategy of controlling the process of comparing very simple relational models (graphs, tables of relationships, trees, etc.) is largely determined by the task of classifying the geometric structures of images and, for practical purposes, does not extend beyond the framework of sequential comparison of the description of the input object with each of its possible reference descriptions. The comparison here differs from the comparison with a reference on the iconic level only by virtue of the type of information compared and the similarity measures used.

The wealth of connections between objects in the real physical world gave the impetus to developing complex relational models (logical systems): semantic networks, frames, and production systems.[2,42,49,52,66] Semantic networks represent objects and relationships between them as a graphic structure with marked arcs and vertices.[3] The relationships between objects and the objects themselves may serve as vertices. Figure 6 presents an example of a very simple semantic network with unary and binary relationships between objects describing a scene in which an armchair, throne, stool, and chair are depicted.[3] The semantic network is a generalization of a conventional graph in the sense that it

makes it possible to consider all possible types of connections between the objects of the real physical world. "Possessing no small possibilities with regard to the wealth of means for reflecting the different relationships between concepts and objects, semantic networks are not very convenient when used in modern computers owing to their too-arbitrary structure and their different types of vertices and links."[8] The attempt to introduce some regularity into the structure of a semantic network led to the appearance of frame representations or frames as one of the subclasses of semantic networks.[1,8,12]

A frame is a regularized hierarchical recursive structure that permits (in a number of cases) using production rules. The frame structure's hierarchy and recursiveness is supported by the mechanism of the frame's slots/components, which in turn may have the names of subordinate subslots, etc., as their meanings. An example of a description of the shape of an object through a base frame and components with the help of a frame is the description of the shape of a ball for points[12]:

(Shape of a sphere 595

(Recess (cylinder under a large finger))

(length 3 cm)

(width 2.5 cm)

(Location 0.1, 0.1)

(Recess (cylinder under a little finger)

(length 3 cm)

(width 2.5 cm)

(Location 0.0, 0.0)

(Recess (cylinder under a medium-sized finger)

(length 3 cm)

(width 2.5 cm)

(Location 0.1, 0.1)

The distinctive feature of this frame is that variables having their own range of permissible values are used to fill the slots. During the processing process when a specific ball for points under observation is being described, these variables receive specific values that are then compared with the permissible range. Whether the values of the variables fall within the admissible ranges or not is what, in the final analysis, determines whether the task of recognizing the object being observed has been performed successfully.

Thus, the level of relational structures (models) has, as its main processing tasks, the tasks of recognizing objects and interpreting images that are accomplished by using processes of comparing relational models of observed objects and images with reference models stored in the knowledge base of the computer vision system. When knowledge about objects and situations in the form of production rules is used, the tasks of recognition and interpretation is accomplished by using logical deduction processes with direct or inverse chains of judgments and processes that are reduced to making decisions on the basis of testing a set of conditions in production rules.[12,63,64]

As a conclusion to this section we present Table 2, which reflects the correspondence between the levels of representing visual information and the tasks, processes, methods, and algorithms of processing it.

Table 2

Level of Representing Visual Information	Processing Tasks	Processing Processes	Processing Methods and Algorithms
ICONIC images	Eliminating amplitude and geometric distortions. Improving quality of visual perception	Amplitude and geometric transformations of images	Flow algorithms of amplitude transformations based on implementation of two-dimensional convolution. Recursive and nonrecursive filtration algorithms in spatial and frequency regions. Fast algorithms for discrete orthogonal transforms
SEGMENTED images	Segmentation of image into like (with respect to brightness, color, or textural properties) regions	Isolation of boundaries of like regions. Marking points of like regions	Algorithms for spatial differentiation, high-frequency filtration, and functional approximation. Algorithms for cluster analysis, building up regions, and relaxation marking
GEOMETRIC STRUCTURES of images	Calculating geometric properties of regions/objects. Constructing structural descriptions of regions/objects	Calculating attributive descriptions of regions. Synthesis of structural descriptions of regions	Algorithms to calculate topological, metric, and parametric primitives. Algorithms to synthesize structural descriptions of regions and boundaries
RELATIONAL STRUCTURES of images	Recognizing objects. Interpreting scene	Comparison. Logical deduction	Algorithms to compare reference descriptions of objects and scenes with descriptions obtained during course of analysis of images. Logical deduction algorithms

3. Strategies for controlling processes of video information processing. The representation levels presented in Table 2 and the respective tasks and processes of processing video information are an expression of the fundamental concept of computer vision. In reality, the form of representing video information upon a transition from lower to higher levels is transformed from signal (random processes and field) to symbolic (relational structures) possessing a significantly higher degree of abstraction and, at the same time, allowing semantic interpretation. Visual data in the conventional scene become data structures that are either difficult or impossible to visualize. Transforming the form of representation results in a change in the processing tasks and processes. Processing processes are transformed from processes of constructing descriptions and models into decision-making (comparison, logical deduction), hypothesis formation, and prediction processes.[2-7]

At each level, processing processes make it necessary to examine additional problems. For example, at the iconic and segmented levels of representation there is, as was mentioned earlier, the fundamental possibility of organizing parallel computations. This type of organization requires solving the problem of synchronizing subprocesses. On the other hand, comparing relational structures poses the problem of conducting the optimum search for a standard for comparison. This may be accomplished by using a number of methods.[49] Finally, the attachment of processing processes to levels of representation is not rigidly specified. Two such tasks are the task of comparison against a standard (the task of combining or tying in images), which provides an example of the processing of comparison on the iconic level[15,16,46] and the task of considering the context of images when segmenting the latter into semantically significant objects, which entails involving knowledge and, consequently, relational structures in the processing process.[51-54]

Everything that has been said points to the urgency of synthesizing methods of controlling the interaction of diverse processing processes both within the main representation levels and upon a transition from one level to another. This is why the concept of the control strategy is actively studied in the literature on the theme under discussion.[2-7,50-54] In the works cited a control strategy is understood as a set of general principles of organizing the interaction of the processes of processing video information within and between levels so that useful information is extracted in the most efficient manner and that redundant calculations are kept to a minimum.[3]

4. The ascending control strategy. The ascending control or, for brevity's sake, the BU [bottom-up] strategy is termed a data-driven strategy.[3,4,7,50] It is termed ascending because the processing processes here are ordered from the lower level of representation to the upper: preprocessing, segmentation, calculation of the geometric attributes of regions, and decision making. The term "data-driven" is explained by the fact that the results of processing data in the preceding steps of the analysis generate hypotheses determining the subsequent steps.[3,7,50]

The BU strategy may be termed traditional, i.e., it reflects the traditional view toward control in the tasks of processing signals and fields and recognizing images. The meaning of the control principle under discussion lies in the fact that a sequential, prespecified chain of processes is implemented for processing video information such that the results of the preceding stage of processing are the source data for the subsequent stage. Several examples are examined below.

Recognizing computer-written and handwritten characters. This task is a classical example of the implementation of a BU control strategy in an important applications area.[55] It is of no little importance that the BU strategy encompasses processing processes all the way up to decision making (representation or identification of a character). Figure 7 illustrates the stage of the transformation of video information in a digital reading automaton.[55] Besides fulfilling its conventional functions, the first step, i.e., digitization and quantization, also includes binarization of the images. The second stage, i.e., localization and isolation of characters, results in a special fragmentation of the image by using input document markers.[55] It may be noted that the preprocessing stage includes two main processes—smoothing and normalization. In the first case we are referring to eliminating the breaks, recesses, holes, and false isolated points in the binary patterns, and in the second case we are speaking of reorienting the character in the required direction (if necessary) and obtaining a skeleton of the character's image. The stage of isolating characters permits the construction of various descriptions of geometric properties that were examined in the discussions on the geometric figures level. In the case where a character receives a syntactic description, the decision making is reduced to grammatical breakdown (derivation) of a phrase of the formal language and establishing the fact of the conformity of this phrase to the grammar's generative rules. In the case where attributive descriptions are used, the decision making may be accomplished by using discriminant functions or correlation algorithms.

Automating the analysis and decoding of industrial roentgenograms. The task of analyzing and decoding x-ray images when using the radiographic method of inspection is not only important and pressing from an applications standpoint, but it also provides yet another example of a situation where processes of recognizing objects and integrating a scene (image) may be successfully formulated and accomplished within the framework of the task of recognizing images by using a BU control strategy. The material discussed below is based on work published elsewhere.[57-60]

Radiographic inspection of products and materials is one of the most widespread methods of nondestructive quality control. The field of industrial radiography is

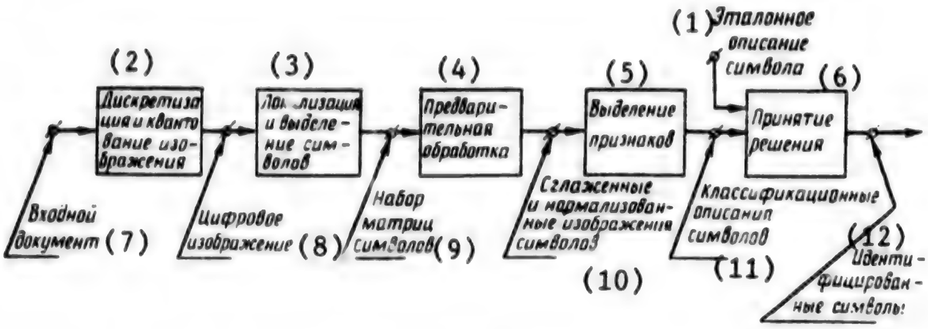

Figure 7

Key: 1. Reference description of character 2. Digitization and quantization of image 3. Localization and isolation of characters 4. Preprocessing 5. Isolation of attributes 6. Decision making 7. Input document 8. Digital image 9. Set of character matrices 10. Smoothed and normalized images of characters 11. Classified description of characters 12. Identified characters

characterized by the massiveness, repetitiveness, and great labor intensity of the implementation of both the production operations entailed in inspection and those operations that are connected with the analysis and decoding of roentgenograms. The analysis and decoding process includes the following stages[61]:

—isolation of defects of a product as regions of optical inhomogeneities in an x-ray image,

—determination of the geometric and photometric characteristics of defects and their types,

—decision making regarding the quality of the product being inspected in accordance with the specified inspection rules.

In most cases the assessment of quality (specifically, the assessment of the quality of welds) is implemented in accordance with a three-point scale in which point 1 corresponds to the highest quality, point 3 to the lowest, and point 2 to the intermediate quality.[61] The classification alphabet in this case may thus be represented in terms of three classes corresponding to the quality points.

The recognition of x-ray images in the specified alphabet of classes includes the following stages of transforming video information:

1. Preprocessing and localizing of the region of the objects' (welding defects') possible appearance.
2. Segmentation.
3. Construction of attributive descriptions of regions of objects (welding defects).
4. Recognition of the type of object.
5. Determination of the spatial relationships of objects and plotting of the relational structure of the description of the x-ray photograph.
6. Reaching a decision regarding the quality point.

The first four stages reflect the transition from an iconic to the segmented and then to the geometric level of representing video information. Stages 5 and 6 implement transformations at the relational structure level.

To recognize the type of object (welding defect) we used the method of sequential dichotomies and attributes (Table 1): z_b being the increment of the value of the defect's brightness relative to the background component; $z_1 = A = d_1/d_2$ being the aspect ratio; $x_2 = T = NS/NP^2$ being the thickness, which is an estimate of the degree of the object's elongation and roundness; and the empirical attribute $x_3 = NS/(ab)$, which gives indirect information regarding the shape of the object's boundaries. Figure 8 shows the tree of sequential dichotomies that describes the decision rule for dividing objects into specified types. In the figure T_A designates the threshold value for the attribute A, and FF designates the value of a linear discriminant function of the type

$$FF = a_1x_1 + a_2x_2 + a_3x_3 + a_0,$$

in which the coefficients a_1, a_2, a_3, and a_0 were defined during the teaching process. The process of recognizing objects, which is generally complicated and laborious, was thus transformed here into a decision procedure using threshold constraints on the values of attributes and linear classifiers into two classes.

The hierarchical relational structure presented in Figure 9 functions as the description of an x-ray image for its subsequent classification in the alphabet $O = (\omega_1, \omega_2, \omega_3)$ (with ω_1 being the highest quality score, ω_3 being the lowest score, and ω_2 being the intermediate score). The nodes of the tree reflect the possible situations, i.e., properties, of the roentgenogram: the presence or absence of defects of a specified type, the presence or absence of spatial relationships between defects, etc. The hierarchy here is generic in nature because the situation at the top level generates the subsituation, etc. The terminal vertices of the tree specify classes of the alphabet O. The ribs of the tree are marked by the values of single-place predicates LP_j ($j = 1, 2, ..., 9$) or by production rules (products) $RULE^{(i)}$, $i = 1, 2, 3$. The predicates LP_j and products $RULE^{(i)}$ (production rules)

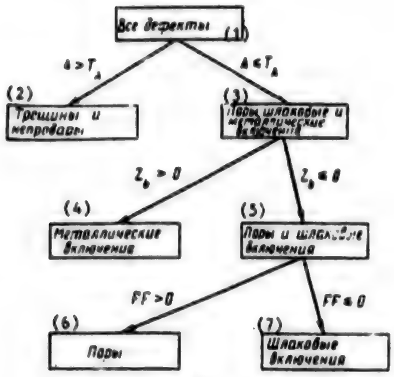

Рис. 8

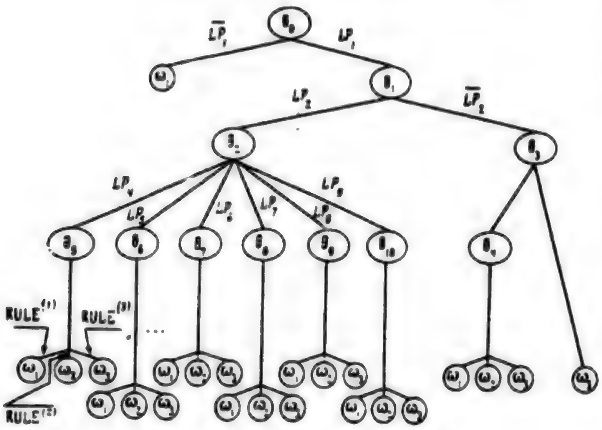

Рис. 9

Figures 8 and 9

Key: 1. All defects 2. Cracks and faulty fusions 3. Pores and slag and metallic inclusions 4. Metallic inclusions 5. Pores and slag inclusions 6. Pores 7. Slag inclusions

of the relational structure of the description of roentgenograms may be specified as follows.

LP_1 (roentgenogram) = true if there are defects, false if there are no defects

LP_2 (roentgenogram) = true if there are composite defects in the chain and agglomerate, false if there are no joint defects

LP_3 (roentgenogram) = true if there are cracks and faulty fusions, otherwise false

LP_4 (roentgenogram) = true if there are chains of pores, otherwise false

LP_5 (roentgenogram) = true if there are chains of metallic inclusions, otherwise false

LP_6 (roentgenogram) = true if there are chains of slags, otherwise false

LP_7 (roentgenogram) = true if there are accumulations of pores, otherwise false

LP_8 (roentgenogram) = true if there are accumulations of metallic inclusions, otherwise false

LP_9 (roentgenogram) = true if there are accumulations of slags, otherwise false

$RULE^{(1)}$: if $[(\gamma_j = 1) \& (B_j^{(1)} = 1)]$, then $\omega = \omega_1$

$RULE^{(2)}$: if $[(\gamma_j = 1) \& (B_j^{(2)} = 1)]$, then $\omega = \omega_2$

$RULE^{(3)}$: if $[(\gamma_j = 1) \& (B_j^{(3)} = 1)]$, then $\omega = \omega_3$;

$j = 4, 5, ..., 10$, where

$B_j^{(1)} = \& (x_k < T_k^{(1)})$, $B_j^{(2)} = \& (T_k^{(1)}$ is less than or equal to x_k is less than or equal to $T_k^{(2)})$, and $B_j^{(3)} = \& (x_k$ is greater than or equal to $T_k^{(2)})$ (with k being a member of the set K_j in all three cases). In these relationships $B_j^{(1)}$ represents logical functions of the numerical attributes x_k and their threshold values $T_k^{(1)}$, $T_k^{(2)}$, and $(T_k^{(1)} < T_k^{(2)}$; K_j represents subsets of the numbers of the attributes; and γ_j is a generic attribute that assumes the value 1 if the situation $_j$ is a precursor of the situation being analyzed. We will note that the term "composite defect" designates the presence in the roentgenogram of a chain or agglomerate of defects, i.e., the presence of specified spatial relationships between individual defects. The production rules reflect an analysis of threshold constraints on the values of a whole series of numerical attributes. These numerical attributes are, for example, the total number of individual defects, the length of a composite defect in millimeters, the minimum distance between individual defects, etc. A total of 36 numerical attributes were used.

The examples of performing tasks that have been presented above, coupled with an analysis of other works,[2-7,50,52,55] make it possible to identify some general traits of the BU control strategy in computer vision.

1. The BU control strategy implements a sequential process of transforming video information generally without using cyclic repetitions, subprocesses, and feedback. The results of processing in the preceding stages become the source data for the subsequent stages.

2. The use of a BU control strategy is characteristic primarily at the iconic, segmented, and geometric level of representation where processes of constructing descriptions and models of objects and phenomena predominate. For the relational level of representation, its use is justified when the tasks of representation and interpretation can be successfully formulated as an image recognition task.

3. In problem-oriented program systems, BU control strategies may be implemented by using very simple methods of organizing and planning computational processes, for example, by using the subject area graphs of an applications package.

5. The descending control strategy. The descending control strategy or, for brevity's sake, the TD [top-down] strategy, is termed a model-driven strategy.[3-5,7,50] It is

termed descending because the processing processes at the lower levels of representation are generated by models and hypotheses set forth at the upper level. It has been noted that the TD strategy strengthens the paradigm of the cognitive approach to understanding the process of perceiving visual information.[4,5] The meaning of the given control principle lies in the fact that a hypothesis about the image or about one of its objects is initially set forth and is then tested in the subsequent steps of the analysis. This hypothesis is set forth in the form of a specific model of an image or object (generally relational), which explains the term model-driven strategy. The main principle of the TD strategy, i.e., to advance a hypothesis and test it, subordinates the initialization of the procedures of processing the bottom levels to the fulfillment of the specified logical conditions and relationships occurring at the top levels thanks to the advancement of some hypotheses or others. It is understood that the BU control strategy is best suited for accomplishing the tasks of representation and interpretation. The hypotheses here may consist of assumptions relative to the types of objects or situations being recognized, and testing them flows over into the process of comparing these objects and situations with reference descriptions. This control principle is evidently least suitable for processing processes on an iconic level since it is difficult to formulate a semantic hypothesis and the goal of processing the video data in precise terms.

As an example we will examine the relational structure of the description of roentgenograms presented in Figure 9. The process of interpreting a roentgenogram (making a decision regarding its quality score) was analyzed above from the standpoint of the BU strategy. The algorithm A1 reflects computational aspects and the structure of the respective program.

An alternative approach may be presented for accomplishing the task of an using a TD control strategy. In this case, as a first hypothesis it is necessary to advance the hypothesis specified by the predicate LP_1, i.e., the presence of defects. The testing of this hypothesis should initiate the operation of an entire set of algorithms on the iconic and segmented levels such that attention is focused solely on restricted sections of the plane of the image (the region of the weld). The result of testing the first hypothesis has the same force as the calculation of the predicate LP_1 and generates the hypothesis specified by the predicate LP_2, i.e., the presence of composite defects, or a decision in favor of a quality score of 1. This process of advancing hypotheses and testing them occurs in strict conformity with the structure of a tree (Figure 9). When j is greater than or equal to 4, the hypotheses advanced are specified by the right part of the production rules $RULE^{(1)}$, and their testing is specified by a calculation of the attributes corresponding to only one of the possible subsets K_j. The algorithm A2 reflects the structure of the decision-making program.

Examples of using a TD control strategy in the task of analyzing and recognizing images of human faces are presented elsewhere.[7,50] It has been noted that this strategy is economical in many cases in the sense that it permits bypassing redundant calculations at the lower levels of representation.[3-5,7,50] At the same time, this control strategy generates too problem-oriented a program that loses its functional suitability not only upon a transition to other classes of images but also upon a change in the conditions of the observations of a given class of image.[7,50] This principle of controlling the process of interpreting data is used widely in expert systems[63,64,66]; however, its main shortcoming for computer vision systems is connected with the absence (at the present time) of effective methods of advancing and testing hypotheses for iconic video data and for video data represented not by hierarchical structures but rather on a relational level.

6. The combined control strategy. The shortcomings of the BU and TD control strategies are, to a definite degree, eliminated by the combined control strategy, which combines both of the mechanisms examined above. The system for interpreting outdoor scenes that has been analyzed elsewhere[50] is an example of such an approach. This knowledge is organized in a system in the form of production rules. Figure 10 is a block diagram of the interpretation system. In the first stage the input color image is segmented into regions that are alike from the standpoint of color and intensity. This is done by using conventional algorithms with subsequent calculation of the geometric properties of these regions. The result is a network of like fragments that store all of the main properties of the fragments isolated (size, color, location, orientation, shape, etc.). The process of preliminary semantic marking (plan, generation, process) is then initiated. In accordance with this process, after the key fragments representing combinations of elementary uniform fragments have been isolated, they are designated by semantic markers. These semantic markers are designated on the basis of a calculation of very simple geometric attributes and binary relationships reflecting the relative location of key fragments. This stage in the processing results in a preliminary interpretation of the image that is termed a plan. Control of the process of transforming video data in the stages listed is organized by using a BU strategy.

The final stage marks the beginning of the process of final interpretation using knowledge about objects and situations organized in the form of production rules. A special production system using logical deduction processes establishes the presence or absence of contradictions in the preliminary marking and initiates (when necessary) processes of remarking regions so that low-level algorithms may be used in the processing of the video data.[50] A descending control strategy is used in the concluding stage since in that stage it is possible to advance and test content hypotheses regarding objects and images as a whole.

Systems to interpret aerial images by using blackboard architecture are organized in a manner that is similar from the standpoint of their control strategy.[7,50] The blackboard is a multilevel data base in the system that is

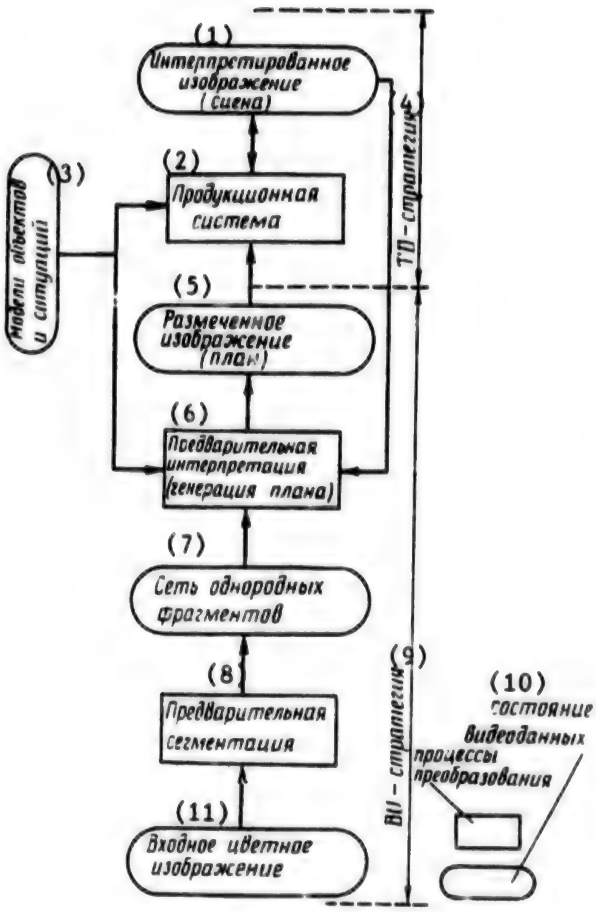

Figure 10

Key: 1. Interpreted image (scene) 2. Production system 3. Models of objects and situations 4. Top-down strategy 5. Marked image (plan) 6. Preliminary interpretation (generation of plan) 7. Network of like fragments 8. Preliminary segmentation 9. Bottom-up strategy 10. Status of video data of transformation process 11. Input color image

accessible to virtually all processing processes storing information about elementary uniform regions, key regions, objects, and categories of objects.[7,30] Elementary like regions are isolated from a source multispectral image by conventional segmentation algorithms, with subsequent calculation of the geometric properties of these regions, which are stored in a property table. The number of lines in this table corresponds to the number of elementary uniform regions isolated, and the number of columns corresponds to the number of attributes calculated. The processes of processing video information that have been mentioned constitute the first phase of the analysis and are implemented under the control strategy.

The next phase, i.e., recognizing semantic objects and interpreting images, is conducted by using production rules specifying one type of object or situation or another. This phase begins with the isolation of key regions that are formed of elementary uniform regions by the merging of the latter. The following are popular types of key regions:

1. Uniform regions that are large in area 2. Shadow regions 3. Regions with high contrast 4. Vegetation regions, etc.

The process of recognizing objects is reduced to testing parts/conditions in production rules and making a decision in favor of one object or another. These production rules may have the following form: IF (a large uniform region) & (a vegetation region) & (not a water region) & (not a shadow region), THEN (a grain field). IF (a high-contrast textured region) & (a vegetation region with a large area) & (not a water region) & (not a large uniform region), THEN (a forest) or (a meadow). The representation process occurs by advancing a hypothesis about an object and subsequently testing it and is thus implemented under the control of a TD strategy. In the event of contradictory interpretations, the system resolves the conflicts that have arisen by a special algorithm.

The main strategies for controlling processes of processing video information in a computer vision system that have been examined do not exhaust all the mechanisms that are possible or that are used at the present time. Because of the limited size of this review, such important control principles as heterarchical control, control with feedback, and others have remained outside of its scope. At the same time, the strategies presented here are fundamental in nature and may be used in conjunction with new mechanisms of organizing computational processes in computer vision systems.

Conclusion. The transition from the lower levels of representing video information (iconic, segmented) to the upper levels (geometric and relational structures) is characterized by an increase in the degree of abstraction of the models of the representation and the degree to which the latter are saturated with semantic information. It is important that each level of representation be dominated by its own processing tasks and processes (Table 2). These tasks of the tasks of constructing models of video data in the different stages of processing are transformed into decision-making tasks in the final stages. The processes of transforming video information also undergo changes from the implementation of amplitude and geometric transformations of random fields, the isolation of boundaries, and the marking of points of images to the calculation of attributive and structural descriptions of regions/objects and compilation and logical deduction with regard to the image's semantic content.

The strategy of controlling the processes of transforming video data permits combining the two fundamental mechanisms of ascending and descending control, thereby achieving great flexibility and reliability.

One should note the directions of research that will take place in the near future that will evidently determine whether the task of constructing real (acting) program

systems for computer vision will be accomplished successfully. They are as follows:

—isolating semantic objects of images based on using expert knowledge, conventional segmentation algorithms, and effective strategies for controlling video information transformation processes;

—recognizing objects and interpreting images based on mechanisms of comparing relational models of the hierarchical and nonhierarchical type;

—developing the architecture of computer vision systems as a special class of expert system that permits (besides the conventional functions of this class of system) a visual interaction with the user.

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Robotizing Machining Under Conditions of Production Redesign

907f0080A Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 8-10

[Article by V. I. Zagurskiy, candidate of technical sciences]

[Text] When creating multiple-machine tool robot systems it is necessary to optimize production and planning (layout) decisions, allow for organizational factors and the availability of trained personnel, etc. The robotization plan should be tied to such enterprise management functions as material and technical supply, technical and economic planning, operations scheduling, power supply, equipment maintenance, provision of tools for the production process, personnel training, major construction, etc. The end results and the time frames required (and actually achievable) to reach them should be specifically reflected in the formulation of the robotization program's goals.

The cost of robotization equipment frequently turns out to be not much less than that of the fixed production assets. Another shortcoming of selecting an industrial robot may lie in the fact that the robot becomes a robot system that restricts the production capabilities of the machining process, above all by virtue of the discrepancy between its payload and the dimensions of the machine tool serviced by it (it is then necessary to refrain from machining workpieces that are too heavy in the robot system even though the machine tool's dimensions permit it).

An even more frequent trouble spot with respect to industrial robots is the insufficient speed and related increase in the operation's auxiliary time. If, for example, the shutdown of the robot system to replace a workpiece amounts to 0.5 minutes and the main production time is an amount on the same order of magnitude, robotization is generally not justified. In this case the main production time should be at least 3 minutes.

Multiple-machine tool robotization is generally resorted to as a way of making more complete use of an industrial robot over time. It must, however, be borne in mind that moderate enlargement of the transport system makes it difficult to operate the robotic system overall and may reduce its efficiency, functional reliability, and operating time.

The possibility of having one industrial robot service a multiple-machine tool system is taken into account during planning. The organization of the latter results from the make-up of its production equipment, which has a similar loading circuit and selection of workpieces that are close in configuration, and this ensures rather long operation of the industrial robot without realignment. The latter is realized to the greatest degree in the case of large-series-type production where a limited range of workpieces is secured to the equipment serviced by the robot. A suitable duration of the machining of workpieces in multiple-machine tool robot systems is 3 minutes and up.

It is preferable to have one industrial robot service two or three machine tools. With the exception of cases where overhead (gantry) robots are used, having one industrial robot service more than four machine tools is hardly encountered in practice in view of the problems related to configuring and selecting workpieces for loading and machining. In the case of a small (less than 3 minutes) piece time, the question of organizing a multiple-machine tool robot system is generally not raised, i.e., the number of industrial robots in the plan is selected to be equal to the number of pieces of equipment serviced. A superficially or insufficiently well reasoned economic substantiation of the robotization plans and an asystematic approach in introducing the industrial robot does not permit adequate loading of the robot. Robotized systems and complexes are poorly written into a production process with conventional organization. The process must be technically updated, and its organization must be restructured.

Under conditions of intensive use of industrial robots, those requirements that have been imposed for robots such as high reliability, speed, design simplicity, service with the guarantee of full operating safety, and positioning precision move to the forefront.

At one of the enterprises in Kurgan, the precision with which a robot configures shafts in the centers of a lathe is increased by using a moving rocking bed 5 (Figure 1) that is mounted together with a rod (9) and bracket (8) on the body (10) of the machine tool's tailstock. The bracket is connected with a counterweight (11) and pressure strip (3). Its position is determined by the diameter of the workpiece and is fixed by a stop (4) and pin (6) mounted on a transverse support. With the help of a clamping device the industrial robot moves the blank (2) to the line of the machine tool's centers with one end into the jaws of the clamping chuck (1) and the other into the bed, after which the clamping device is withdrawn and the blank is secured to the movable tailstock center (7).

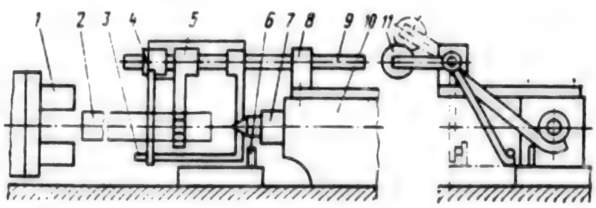

Figure 1

During the machining the pin (6) moves together with the longitudinal support, sliding along the pressure strip. The strip moves in an angular direction, and the bed is moved out so as not to impede the machining of the workpiece by the cutting tool and the removal of the chips. Under the effect of the counterweight the bed turns to the initial position and grips the workpiece when the longitudinal support is withdrawn.

The device is easy to realign, and this makes it possible to compensate for the robot's imprecision in the positioning the workpieces, which is particularly reflected when the shaft is long and the center holes are small.

The load on the industrial robot in a multiple-machine tool robot system is higher than in single-machine tool systems. The following information is analyzed for correct plotting of the industrial robot's sequential motions as it operates in accordance with a standard subroutine for a two-machine tool robot system in a wait mode: the machine tools' requests for a servicing object (proceeding from the presence or absence of workpieces on the machine tools); the presence of workpieces in trays or cradles (which makes it possible for the robot to grip them); the presence of free spaces, i.e., positions, in the trays (which makes it possible for the robot to place workpieces there), etc.

Requests for service are used by the robot in the first stage of loading and unloading the machine tool positions. The transition to the second stage occurs when there are no such requests and, consequently, begins the operation of transport between the machine tools and several other operations included in the program controlling the industrial robot's actions. After each subroutine is completed, the system returns to the request stage to keep the machine tools' downtime to a minimum. In a multiple-machine tool robot system after a specific machine tool is loaded or unloaded, the subroutine stipulates a request to service the other machine tools in the system. If one machine tool or other in the robot system is a limiting factor owing to its productivity, the wait subroutine calls that particular machine tool first. A widespread technique geared toward reducing the idle time of equipment consists of formulating a preliminary call a specific time before the completion of the operation of machining the workpiece, in which case the industrial robot has time to perform such previously specified actions as taking a workpiece to be machined and transferring it to the machine tool. After the machining has been completed, there is a final call for the industrial robot to complete its actions in loading or unloading the machine tool.

A forecast of calls to service machine tool positions in the robot system that is connected with an assessment of the probability of a call before a higher-priority call is received may lie at the basis of the wait subroutine. This permits more rational servicing of the machine tool positions and makes it possible to work out auxiliary subroutines with an allowance for the current position of the industrial robot before a request to service the robot system's primary equipment is received. Thanks to this more complicated organization of the control process, the productivity of the complexes and systems, which are themselves characterized by a rather complicated structure and operation, is increased.

The probability approach is not used in simpler cases. For example, in the model LAS ChPU 13 quick-realigning robotic automated line (Machine Tool Plant imeni S. Ordzhonikidze), machine tools may be automatically loaded by a robot in any sequence owing to reprogramming of its operation and main memory by the teach method. The control programs are stored on magnetic tape.

Over the course of the robot system's operating cycle there are time losses related to loading and unloading and other auxiliary functions. When a robot uses a two-grip device for manipulation, these losses are reduced significantly, as they also are in the case where the industrial robot's work schedule is plotted in a rational manner. The robot's control algorithm allows for the waiting for a request to service a machine tool. Depending on the situation, servicing, i.e., loading and unloading the machine tool by means of an industrial robot, is either performed, or else there is a transition to the performance of such auxiliary functions as laying workpieces in a tray and taking a blank from the magazine, which are performed while a workpiece is being machined on a machine tool.

The efficiency of using an industrial robot to automate machining thus depends not only on a correct selection of the model of industrial robot but also on the rational solution of the entire set of problems entailed in robotizing a computer-integrated manufacturing system. The control program of the industrial robot servicing the production equipment is determined by both the design of the industrial robot itself and the makeup of the robot system. The development of an algorithm for the robot system's functioning precedes the direct programming.

Ever-increasing attention is being paid to simulation when creating FMS with a high level of structural organizational. For this purpose, computer programs are being created that may be used to research and optimize the operation of an FMS over time after modifying its structure or individual parameters. Performing the task of synthesizing the structure of a complicated FMS by the same method is still difficult, but partial tasks are being solved successfully. One is to analyze the productivity of a section consisting of two robot systems, the layout of which is presented in Figure 2. Here the first robot system (PTK-1) is an ASVR-01 robot system to machine shafts, and the second robot system (PTK-2) is a system for turning shafts on a lathe. Their cycle times are 16 and 26 minutes, respectively. The numbers in the figure indicate the following: 1, machine tool position for milling and drilling center holes in blanks; 2A through 2E, model 1B732F3 NC semiautomatic lathes; 3A and 3B, model UM60F2.81.01 industrial robots; 4A through 4D intermediate (between the machine tools) storage units with capacities of 5 to 12 workpieces); 5A and 5B, storage units for machined shafts; 6 and 6A, storage units for blanks; 7A and 7B, intermediate transporters between the first and second robot systems; 8, storage units located at the machine tools (each holding two workpieces). The broken lines indicate additional devices in the section for an automatic transport link between the two robot systems.

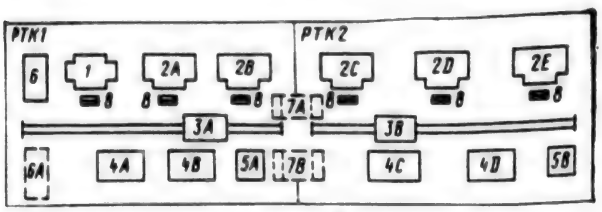

Figure 2

All of the blanks entering a section undergo milling and centering on a machine tool (1). The first and second robot systems operate separately for the remainder of the machining. After preparation of their bases, the blanks for the first robot system are transferred by a robot (3A) to a storage unit (4A). From there they are transferred to machine tools (2A and 2B) for turning on a lathe. The blanks for the second robot system (after preparation of the bases on the same machine tool (1)) are transferred by robot (3A) to a storage unit (6A). From there the shop transport feeds them to machine tools (2C and 2D) serviced by a robot (3A) for turning on a lathe. The finished workpieces are put into storage units (5A and 5B) by robots. The machine tool (2E) is a stand-by machine.

The Machine Science Institute imeni A. A. Blagonravov of the USSR Academy of Sciences analyzed the productivity losses of a similar section as a function of the duty factor ρ and the industrial robot, and it equals the ratio of the average time spent by the robot to transport a workpiece from the beginning to the end of the machining process on all of the machine tools in the robot system. The productivity of the robot system was assumed to equal 100 percent, with the robot service time going to zero for all of the transport operations. The existing technology and organization of the production process correspond to values of the coefficient ρ equal to 0.2 and 0.16 for the first and second robot systems, respectively. The significant underutilization (from a time standpoint) of both industrial robots in the section above all leads one to think that its productivity could be increased by reducing (to a fourth) the time required for turning on a lathe.

Only when ρ equals 0.8 for the first robot system and 0.64 for the second would the respective systems servicing the complexes turn out to be loaded to the degree that would require increasing their speed (i.e., installing a different model industrial robot) or using a flexible manufacturing section with a different structure.

This example shows that equipping the first and second robot systems with separate robots is justified in the case where the operating cycle of the main equipment is rather low. At the same time it is clear that, given the existing technology and the machine tool's shaft-machining capacity assumed in our example, it is feasible to design a link between the complexes of the first and second robot systems by using an intermediate transporter (7A) that is simultaneously a storage unit for the second robot system. Both robots (3A) and (3B) have access to this transporter. The section's operation may be organized so that the blanks for the second robot system, after having passed through the machine tool (1), are placed on the transporter (7A) by a robot (3A). The other robot (3B) takes blanks from it and transfers them to the machine tools (2C) and (2D). In the given case the robot (3A) services five machine tools (on which workpieces belonging to both product lists are lathed simultaneously) without any loss in the productivity of the two robot systems.

However, at values of ρ equal to or greater than 0.4 for the first robot system and 0.32 for the second, the same organization of the section's operation entails a significant loss in productivity. This means that a second transporter is required for links between the first and second robot systems, for example, at values of ρ such as 0.8 and 0.64, respectively. A robotized carriage may serve as such a vehicle.

Nothing was said above regarding allowing for the operating reliability of the production and auxiliary equipment, although the stand-by machine (2E) was mentioned (it belongs to the lathe group and assumes functions analogous to the machine tools of both robot systems in the event of their failure).

The problem of further popularizing robotization in the field of machining is not reduced solely to making successful use of existing and new designs for industrial robots and production equipment. The following may be considered the pledge of robotization: using more advanced (in a functional respect) production equipment; configuring the industrial robots used from standardized building units, i.e., modules; the capability of selecting a wide range of auxiliary hardware needed to create flexible manufacturing modules, robot systems, and FMS; and the ease and speed of realigning the robotized technology in a multiple-product production process (including automatic changing of the grips of the industrial robots themselves).

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New Robotized Assembly Method

907f0080B Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 10

[Article by V. N. Davygora, candidate of technical sciences, V. A. Kirilovich, and V. A. Orlyuk]

[Text] The Machine Building Technology Department of Kiev Polytechnic Institute developed a new robotized assembly method (author's certificate 1458126) to expand the manufacturing capabilities and increase the reliability of the process of assembling coaxial multielement three-dimensional structures by using assembly industrial robots. Using the given method in conjunction with a device for its implementation makes it possible, given suitable time and labor expenditures, to assemble products having joints that are either impossible to assemble in a quality manner when conventional methods are used or that require advanced software, algorithms, and a computer to control the process.

The method is based on redistributing the function of mobility during the assembly process between the robot and the assembly attachment. It entails securing the first workpiece in a fixed position in the robot's working head, moving it in accordance with a program with three degrees of freedom to the device, and securing the first workpiece with subsequent joint construction. Before the beginning of each subsequent joining operation workpieces are brought into contact with one another along their faces. Next the fastened and fixed first workpiece is unfastened to allow it to effect a free linear motion in a plane perpendicular to the direction of the assembly force of the joint being made and a free angular movement in space. When the joint is made, the first workpiece is fastened in the resultant position. The connection between the working head and the workpiece fastened in it is then broken, and the process is completed until the structure is fully assembled. Before each subsequent workpiece of a multielement structure is joined, the first workpiece is returned to its initial position and secured.

Implementation of the method presupposes the following sequence and makeup of the production interactions between the robot and elements of the assembly attachment with the elements being assembled. The workpiece (18) (Figure 1b) is mounted in a fixed position in the robot's live zone, for example, on the bed (not shown) of the disk (10) (Figure 1a) of the assembly device, and the electromagnets (11) are switched on. The axis of the workpiece's joint surface occupies some initial position. After this, a workpiece (17) is secured in the robot's (not shown in the figure) working head (16) and is moved by the robot in accordance with a program with three degrees of freedom to the device that secures the next workpiece (18). The workpieces (17) and (18) are brought into contact along their faces, after which one of them (18) is unfastened by switching on the drive (14) of the clamp (6). The latter moves up, sliding along the outer surface of the case (5). Under the effect of springs (8), a ring (12) unfastens the spherical sleeve (9), thereby giving the disk (10) with the workpiece (18) located on it the capability of free linear motion in a plane perpendicular to the assembly direction (i.e., in the plane of the case's (5) face) and free angular motion in space thanks to the mobility of the hinges. The joint is

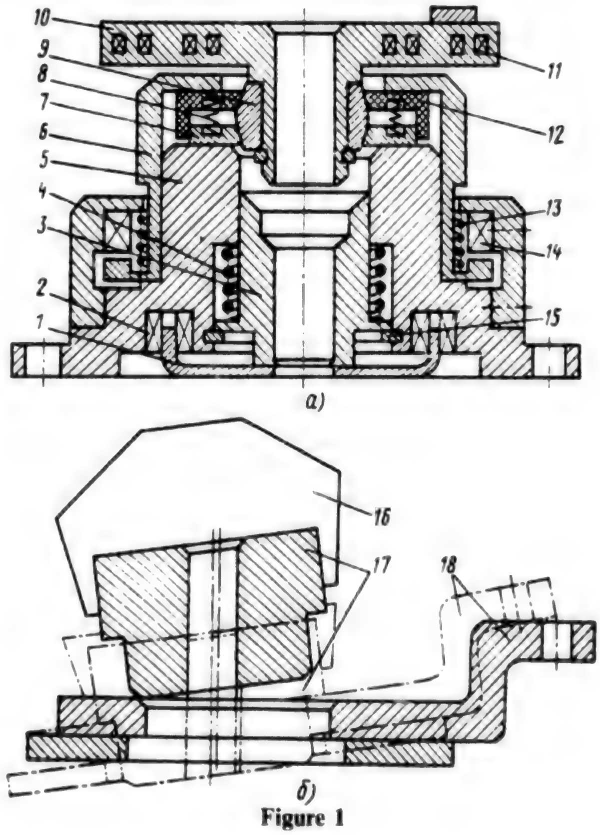


Figure 1

made, with the assembly force making the workpiece (18) assume a position different from its initial position. When necessary, the workpieces are split apart, which is provided for by an opening in the disk (10).

The component (18), which is now in a position other than its initial position (shown by the broken line in Figure 1b), is fastened. The drive (14) is switched off, and the clamp (6) (owing to the action of the spring (13)) presses a ring (12) with a spherical surface to a spherical sleeve (9). A force closure of the system clamp (6)-ring (12)-sleeve (9)-ring (7)-case (5) occurs. The working head (16) then releases the workpiece (17), the next workpiece (not shown in the figure) is secured in the head, and the process is repeated. Analogous actions are performed until the structure is fully assembled.

Before each subsequent structure is assembled, the workpiece (18) is returned to its initial position by switching on the drives (14) and (2) with an armature (1) to control the standard (3). The latter, which is fixed relative to the case (5) by a check ring (15), moves up along the inner surface of the case (5), pressing the spring (4), and makes contact with the face of the disk (10). Initially it makes contact with its face, after which its centering belt makes contact with the disk's basing surface. The disk and workpiece (18) return to the initial position. The drives (14) and (2) are switched on sequentially, thereby securing all of the elements of the product in the initial position. The structure assembled in this manner is unfastened and removed from the device. The next workpiece is mounted, and assembly of the next structure continues.

UDC 658.527.011.54;669-493.004.8.002.5

Mechanized Section To Process Metal Chips

907f0080C Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 11

[Article by Yu. A. Kostin and Ye. V. Sorokin]

[Text] The continuous increase in the volumes of metal working that is characteristic for the contemporary level of the development of machine building has increased metal chip wastes, which are a valuable secondary raw material for metallurgical production. However, using chips in unprocessed form has significant drawbacks. Their low bulk density (0.3 to 0.6 t/m^3 and the presence of oil, emulsion, and oxide on their surface worsens the quality of the smelted metal and reduces the productivity of steel-melting units. Storage and transport of unprocessed chips requires additional production areas and a large amount of transport equipment and leads to irrecoverable losses.

The proposed section is intended for processing curled steel chips (type 16A and 16B and the group B13 according to GOST 2787-75) by the cold briquetting method to bring the resultant secondary metals to the quality standard's requirements and may be recommended for machine building enterprises with a yearly metal scrap yield of more than 5,000 tons. The type of finished product, i.e., briquettes No 1 and No 2 and chip No 1, are in accordance with GOST 2787-75. The section developed is distinguished by the fact that it provides an integrated solution to the problems of mechanizing the process of processing chips and moving them between operations. The chip processing section's design is based on series-produced (by domestic industry) automatic equipment. The chip processing process calls for two-stage crushing, sieving, cleaning to remove cutting fluid, cold briquetting, and collection and removal of the cutting fluid.

The chips are loaded into the bin of the breaking device of a model SDA-7 chip crusher unit (2), where the primary crushing takes place. After this the chips are fed by belt conveyer to the unit's hammer crusher (not shown in the figure), after which they are transported by scraper conveyer (6) through a chute with a gate (7) mounted on the bottom of the conveyer and then to a vibrating sieve (5) for sieving. After being sieved, the chips move along a sloped trough (4) into the intake

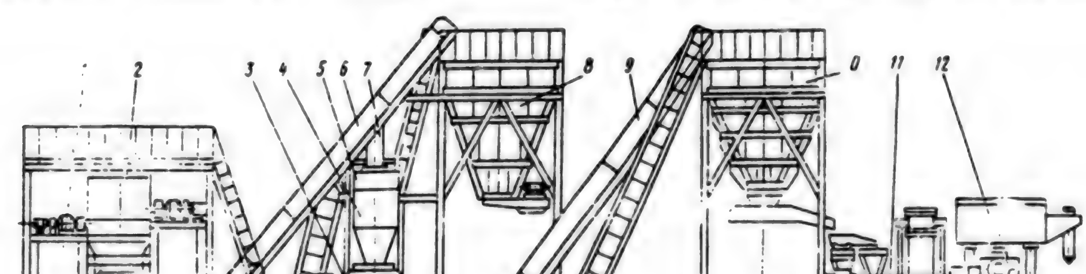


Figure 1

hopper of a model FVV-1121U-01 centrifuge (3), where the cutting fluid is separated from the chips. The cutting fluid is collected in settling tanks (1). The large pieces of chips and uncrushed bodies that did not pass through the sieving are sucked from the vibrating sieve along a sloped trough into an open tray. The degreased chips are transferred by scraper conveyer (9) out of the centrifuge and into a storage bin (10) equipped with a vibrating feeder that is used to feed the chips to the intake chamber of a model B6238 briquetting press. The finished briquettes are rolled from the press along a sloped chute to an open tray (11). In the event that the centrifuge or press fails, the chute with the gate (7) is closed, and the chips enter a storage bin with a gate valve (8) for subsequent loading into an automotive transporter.

The section may be controlled in both offline and centralized modes. In the offline mode the equipment's operation is controlled from its own panels. This mode may be used in setup operations and in partial operation of the equipment. In the centralized mode the section operates from a single control panel to which are sent signals of the status of the units and control organs so as to permit quick intervention in their operation.

The section has a chip processing productivity of 2,500 kg/h. Eight people service it. The economic effect from introducing the section is achieved by shaping the chips into briquettes, which have a higher procurement price, and amounts to 80,000 rubles.

UDC 658.52.011.56.012.3.005;681.586;531.7.08-52

Postoperation Automatic Inspection in FMS

907F0080D Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 12-14

[Article by N. Ya. Ilchenko, candidate of technical sciences, and A. S. Mironenko]

[Text] The introduction of flexible manufacturing systems provides for (besides automation of the main operations) a significant increase in the quality of the product output (excluding human participation in the making of conclusions about its acceptability) by creating an inspection system that is adequate from the standpoint of its automation level and reliability and the productivity of the hardware for the machining process in the FMS. At the present time the labor intensity of inspection of the linear and angular dimensions and positioning errors of the surfaces in workpieces that have been machined reaches 20 percent of the total labor intensity. The automation level does not exceed 1 percent, which in and of itself makes work to automate and increase productivity during inspection operations urgent.

Two types of inspection are used in FMS. They complement one another and form a unified system. Built-in inspection of the most strictly specified geometric parameters of a workpiece ensures automatic alignment of the equipment when a parameter being monitored is outside the tolerance zone. Postoperation multiple-parameter inspection based on measurement of a representative sample of workpieces and information processing makes it possible to draw a conclusion regarding the stability of the entire production process in an FMS and the acceptability of a batch of workpieces. Depending on the nature and size of the deviations, the result of the inspection either dictates or eliminates the need to align the entire FMS.

A system for postoperation automatic multiple-parameter inspection of workpieces that operates as a component of an inspection station has been developed for a metal working FMS. Sixteen type 76503-02 transducers with a measurement range of plus or minus 1 mm are used as a primary information source in the system. Components are loaded into the measurement system, which is available in two versions—for flange- or sleeve-type workpieces and for shaft- or axis-type workpieces. The loading may be done manually or by an NTsTM-01 Elektronika-type robot. The range of measurable workpiece parameters is as follows: 10 to 80 mm for the diameter and 40 to 200 mm for the length of shaft-type workpieces and 10 to 100 mm for the outer diameter, 20 to 80 mm for the inner diameter, and 5 to 150 mm for the height of sleeve-type workpieces. The following parameters may be monitored: diameter, length, ovality, coaxiality, and radial and facial wobble. The measurement error is 0.005 mm.

Figure 1 is a block diagram of an automated inspection station for multiple-parameter postoperation measurements. Besides a measurement complex (1) the inspection station includes a measuring and readout unit (2) with YeS5088 small-sized floppy disk storages, an inspection station control unit (3), and an industrial robot (4) with its own control system. The electronic

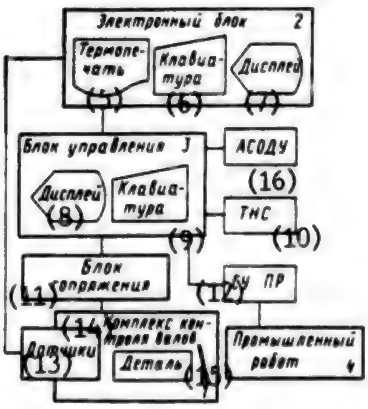


Figure 1

Key: 1. Shaft inspection system 2. Electronic unit 3. Control unit 4. Industrial robot 5. Thermal printing 6. Keyboard 7. Display 8. Display 9. Keyboard 10. Transport and storage unit control system 11. Interface unit 12. Industrial robot control system 13. Transducers 14. Shaft inspection system 15. Workpiece 16. Operational supervision

measurement and readout unit performs the function of measurement data I/O and processing (including statistical processing) of files of information extracted from the transducers. The electronic unit has a built-in keyboard, a thermal printer that records the inspection results, and a display that displaces the input data and the results from the inspection and statistical processing of the data. The keyboard is used to input the values of tolerances, and the deviations of a specimen workpiece from the rated values are input into the electronic unit's memory to control the course of processing the measurement results.

A control unit based on a Neyron AZ-A14 microcomputer controls the structural components of the inspection station-measurement system, the electronic unit, and robot and switches the inspection station off after it has completed its operation or in the event of a soft failure in its operation.

The universality of the proposed technical inspection is achieved by group inspection technology and the capability of realignment by changing calipers and the inspection program and processing the results. The inspection station may be used both as a measurement system attached to a machine tool and when formulating inspection sections for an FMS. Figure 2 presents the layout decision of an inspection section that includes a type NTsTM-01 Elektronika-type industrial robot (3), a shaft inspection system (4), a system (8) to inspect sleeves and flanges, and a control unit (5). An automatic transport and warehousing system is used to bring trays (6) with workpieces to this section. It consists of a transport carriage (1) and replaceable storage devices including a turning storage unit (2) and replaceable containers (7) and (9).

One inspection station ensures a high productivity of multiple-parameter inspection of workpieces (30 seconds to inspect one workpiece with respect to eight parameters).

The inspection station's operation is programmed in BASIC, and the parameters with respect to working out the modes are specified in interactions either from the keyboard or else from YeS5088 floppy disk storage directly at the inspector's workstation. The inspection station control system can operate in the following basic modes: control system links, daily/shift assignment and

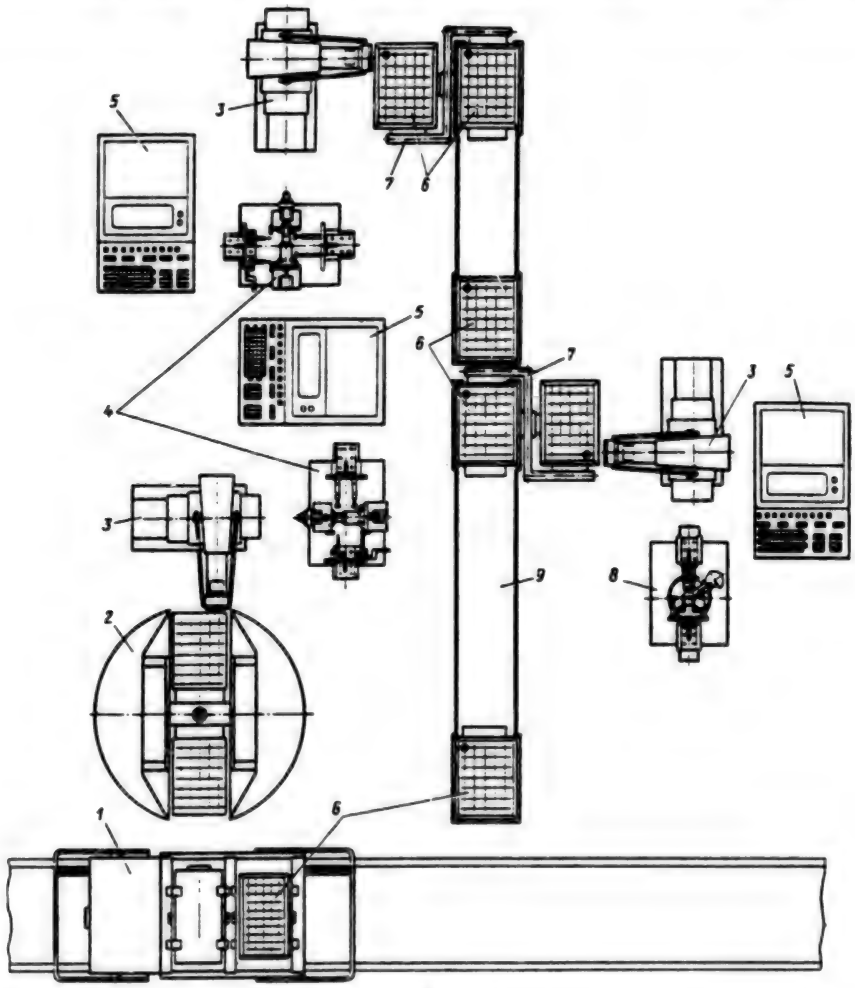


Figure 2

transport and storage unit, alignment, and offline. An operator selects the mode by selecting a digital code from a program menu.

The control system link mode provides for operations in different versions of the inspection station's configuration (with or without a robot) and different versions of using the inspection station (with an automated transport system present or with an automatic link to the operational supervision system present).

The second operating mode, which is implemented in the presence of a link with the operational supervision, produces the daily/shift assignment, the structure of which contains information about the workpiece code, operation number, order number, lot size, number of units per tray, and other data regarding the measurement system including the tag of the batch being inspected. When working in this mode the operator also has the capability of changing the order of the workpieces inspected or requesting that batch from the warehouse (by using the bring instruction) that is next in order according to the daily/shift assignment after sending the workpiece code to the transport and storage unit control system.

The alignment mode is used to input variable data characterizing the operation of the inspection station and controlling the fulfillment of its individual functions. When this mode is entered, a videogram is output to the screen. It contains the following submodes: input data on mechanisms, input data on the robot, debug the mechanisms, and debut the robot. The operator works out the necessary instructions for each of the videogram's positions. The alignment mode provides for the output of diagnostic messages in the event that accident situations arise.

The latter mode specifies the inspection station's operation from a start button in accordance with the established algorithm and without the operator's participation.

The production process monitoring subsystem, which is implemented by using an inspection station based on a multiple-parameter measurement system and equipment for built-in active monitoring and diagnostics in the flexible manufacturing module, is a structural component of the automated control system of the FMS. The block diagram of the control of an integrated FMS including a production process control subsystem is presented in Figure 3 [not reproduced]. Included in the diagram are the group control system, the diagnostic equipment, and the procedures for inspecting a workpiece. From a functional standpoint the production process control subsystem tracks the technical status of the equipment and the product quality in real-time.

This type of interpretation of the subsystem determines the structure of the information streams that (in the system under development) are realized in the direction from the production process control subsystem to such automated enterprise management systems as the automated technological process control system, the operational supervision system, and the automated system for technological preparation of production. It is this direction that (depending on where it belongs and whether it is requested) information on the number of the given piece of equipment, the date on which the check measurements were made, statistical data, and a conclusion regarding the acceptability of the batch inspected and the amount of defective production are sent. A message about failures and their causes is also sent. When analyzed by the subsystems of the automated enterprise management system, the resultant information makes it possible to take timely measures to fine-tune and repair the equipment, correct the daily/shift assignment, optimize the machining modes and route, and resolve a number of other production matters. The specific users of this information are the production department, the chief mechanic's office, the production control department, and other management and planning services. As of today, however, there are no systems permitting practical use of this information.

Until recently, when developing production a great detail of attention was given to directly solving the problems of automating the machining of workpieces. The pace of the increase in the technical level and organization forms in this sphere essentially determined the progress that has been made in the sphere of technical monitoring, the forms of its organization, and its metrologic support. Under the conditions of computer-integrated manufacturing, the importance of the information obtained in a production process monitoring system, its increasing (as the automation level increases) degree of reliability, and the increasing complexity and validity of selecting an inspection method and inspection equipment have moved solving the problem of inspection to the ranks of top-priority tasks.

The measurement system developed made it possible to use software and algorithms to compensate for errors in the skew and displacement of the axis of a workpiece when configured relative to the axis of the base nodes of the measurement system.

UDC 621.865.8-113:621.757.06

Assembly Robot System

907f0080E Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 14

[Article by I. S. Khomak]

[Text] This robot system, which has been created on the basis of two model IR5-2E industrial robots, is intended for assembling a metal axis 3 to 5 mm in diameter and 20 to 45 mm long with sleeves 20 to 50 mm in diameter and 2 to 4 mm thick (the flywheel of the inertia mechanism

of a child's toy consisting of an axis and two disks) by the method of sinking the metal of the sleeve at the pressing site.

Two industrial robots (1) and (13) are mounted on a T-shaped table (2). The robots are equipped with gripping mechanisms (15) and (12), a lever press (7), a die (14), a separator chute (8), a gate feeder (4) with a chute (5), and a post (3) with transducer and dump chute (16). Universal posts with vibrating bins (6) and (9) (the position of which can be regulated in the horizontal and vertical planes) are fastened to the table on vibrating supports.

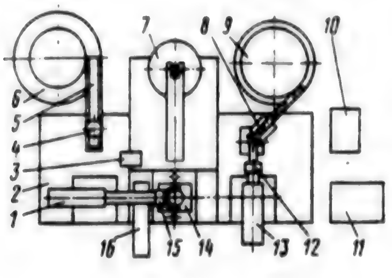


Figure 1

Located inside the T-shaped table are pneumatic equipment and a device to check for the presence of a workpiece in the vacuum gripping mechanism (12). Located alongside the T-shaped table are a control column (11) consisting of an MKP-1-32-05 programmable microcontroller, a feed unit, a control unit, and a unit to pump out air (10) that has been created on the basis of a 2NVR-5D vacuum impeller pump, receiver, and vacuum gauge.

The workpieces being assembled (disks and axes) are loaded into the vibrating bins in bulk. The axes proceed from the vibrating bin (9) to the tube of the separator chute (8), which is a storage unit. From there they are issued piece by piece in a vertical position to the position of the gripping mechanism. Two sequentially activated electromagnets that play the role of separator gates are used for the piece-by-piece feed. The industrial robot's (13) gripping mechanism takes an axis. The industrial robot then turns its arm 90 degrees, extends it, lowers it, places the axis in the die, and returns to its initial position.

At the same time, disks travel from the vibrating bin (6), along the chute (5), to the gate feeder's storage unit. The gate sends them in pairs to the position of the gripping mechanism. The robot's (1) mechanical gripping mechanism (15) takes the two disks, turns them 90 degrees, extends and lowers itself, and places the disks onto a spring-loaded orienting table, guiding them to the end of the axis that has been placed in the die. Next, the arm with the gripping mechanism moves out from under the press. The lever press presses the disks, after which the orienting table with the finished product returns to the upper position and the robot's (1) arm extends and takes the product from the die. Upon returning to the initial position it dumps the finished product into a chute (16), from where it proceeds to a tray.

All of the robot system's moving parts, with the exception of the gate feeder, are equipped with transducers monitoring the end positions. The presence of disks in the mechanical gripping mechanism is monitored by a KVP-16 noncontact transducer located on a post (3), and the presence of an axis in the vacuum gripping mechanism is monitored by a pressure-vacuum gauge located on a pneumatic panel inside the T-shaped table. During operation in an automatic mode, the absence of a signal from any of the transducers causes the robot system to shut down.

The control column allows the robot system to operate in automatic, step-by-step, and manual modes. The manual and step-by-step modes are used during alignment operations.

The program is input by the programming device of an MKP-1-32-05 microcontroller.

Lamps on the control unit's face panel are intended for indicating a malfunction of the mechanisms in the event of a failure in the system's operation.

The robot system has a productivity of 8 assemblies per minute and a power consumption of 0.8 kW. Depending on the type of pressing, the force developed by the lever press amounts to 12 or 16 kN during plunger courses of 55 and 45 minutes, respectively.

UDC 621.865.8-238.82-755

Large-Payload Manipulator

907F0080F Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 14-15

[Article by S. I. Sladkov, candidate of technical sciences]

[Text] Articulated balancing manipulators with a payload up to 320 kg are used in the equipment at machine tool operators' workstations. The most popular of them are the ShBM-150 of the Kramatorsk Machine Building Scientific Research, Design and Technological Institute, the KSh-160 of the Kompleks Scientific Production Association in Volgograd (manufactured by the Mogilev Automation and Mechanization Equipment Pilot Manufacturing Plant), and model KM932 loaders from the Krasnodar Experimental Plant imeni Kalinina.

In all of the aforementioned manipulators, moving the vertical boom so that it deviates from the vertical must be done manually. When the mass of its load is large, moving it requires applying a large horizontal force. In the KM932 loader, for example, the horizontal force must exceed 70 kg when the load has a mass of 160 kg.

Introducing a second link into the mechanical system eliminates the need to have the boom deviate from the

vertical. In the lifting and transport device (author's certificate 1206224) the upper two-arm lever (13) is restrained by a ball joint (12) on a supporting platform (9), and it is connected with a vertical rod (6) via a ball joint (7). A lower tow-arm lever (16) with a gripping mechanism (3) is connected to the lower end of this rod through a cylindrical hinge.

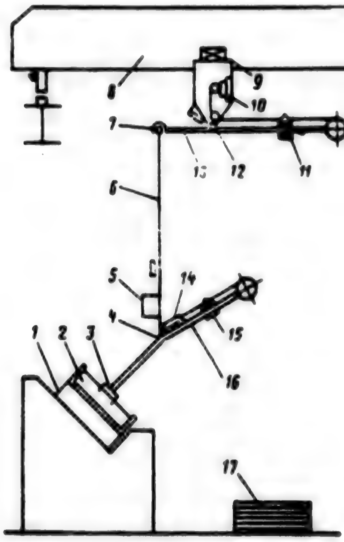


Figure 1

Balancing weights (11) and (15) are mounted on the free arms of the levers (13) and (16). They move along the levers through tension mechanisms with the help of drives (10) and (14). A control panel (5) is mounted in the lower part of the vertical rod. It sends a signal to operate the gripping mechanism and balance the load. The turning of the levers around the hinges (12), (7), and (4) and the vertical movement of the rod are accomplished manually with minimal force.

During the simultaneous turning (perpendicular to the plane of the sketch) of the upper lever (13) around the hinge (12) and the lower lever (16) around the hinge (7), the workpiece (2) moves to any point on the horizontal plane. Additional vertical movement of the rod feeds the workpiece to any point in space within the bounds of the workstation without the application of additional force. The manipulator's payload depends solely on the strength of the structure and the precision of the position of the counterweights.

The manipulator moves a workpiece, for example, from a stack (17) to the product being assembled. The beam-track-and-trolley hoist (8) is used solely to move from one workstation to another and for roughly locating the manipulator over a stack of workpieces.

UDC 658.527:621.789

Line To Roll Collar of Cup

907F0080G Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 15

[Article by V. I. Guner]

[Text] The Avtokuzlitmash Planning, Design, and Technology Institute in Rubstov has created a line for rolling the collar of a cup (author's certificate 530718). All of the operations on the line are implemented by using hydraulics.

A measuring blank (diameter, 100 to 200 mm; wall thickness, 10 to 25 mm; and length, 70 to 180 mm) is cut out on a tube-cutting machine (1). The blank rolls along a chute (2) to a separator (3). The latter issues one blank at a time to a pneumatic hoist (4) that lifts the blank to the level of the chute (5) of the heating unit (8). The blank rolls along the chute to a separator (6), which issues one blank at a time to the axis of the heating unit. A pusher (7) pushes the blank to the work coil (10) of a heating unit (capacity of the high-frequency current converter, 250 kW; frequency, 2,400 Hz). After the face of a blank has been heated (55 seconds), the pusher (7) pushes the heated blank out (cold end first) as it loads a new blank into the work coil. The operator grips the heated blank (11) by the cold end, loads it into the die (16), and switches the drive (20) on. The mechanism (12) quickly feeds the flanging roller (14) to the side of the heated blank located in the die. After the blank reaches the feed speed, the roller slows down. The roller then deforms the metal for 22 seconds, forming a collar with a height determined by the position of a controllable stop (13).

When the collar-shaping mechanism is lowered to the stop (13), its roller still sizes the face surface of the collar for some time. The deformed metal reaches the surface of the edging roller (15), which shapes the collar's surface along the outer diameter, with the diameter of the latter controlled by the positioning of the roller (15). After the collaring has been completed, the roller (14) withdraws to its initial position, the drive (20) is switched off, and a pusher (17) pushes the workpiece out of the die along a chute (18) into a tray (19).

The line is quickly realigned for another workpiece with the form of a body of revolution. Its simple design makes it reliable to operate and convenient to service.

The line for rolling the collar of a cup has been introduced at the Altay Tractor Plant with an economic effect of 238,600 rubles. It has a productivity of 60 workpieces per hour. Its overall dimensions are 4,000 x 3,700 x 3,400 mm.

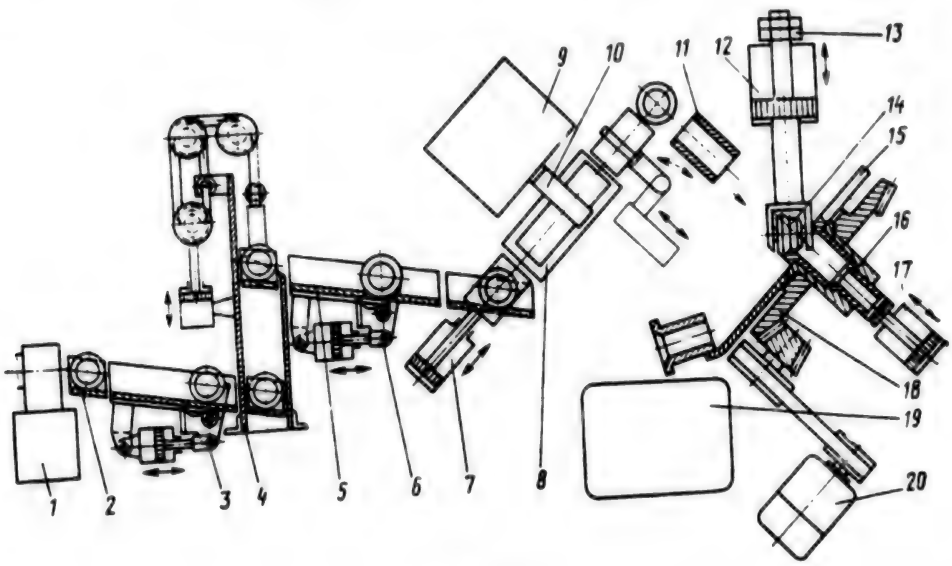


Figure 2

UDC 62-231.223

Rolling and Sliding in Screw-Type Ball Mechanisms

907F0080H Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 15-16

[Article by I. B. Shenderov]

[Text] Screw-type ball mechanisms, which have ease of movement, high efficiency, and precision of movement, are difficult to replace in precision machine tool and machine building. The theory of screw-type ball mechanisms is rather well developed; nevertheless, the general machine building literature contains imprecise descriptions of the mechanisms, particularly with regard to calculating their efficiency. It is assumed that screw-type ball mechanisms differ from screw-slide nut gearings by virtue of the substitution of slide friction with rolling friction, and formulas analogous to those from calculations of conventional helical gearings have been proposed for calculating the efficiency of these mechanisms. The discrepancy between such a theory and practice is quickly becoming apparent in recommendations that coefficients that are incomparably larger than those used during the rolling of, let us say, roller bearings be used when calculating the coefficient of resistance to rolling.

Correct design of drives with screw-type ball mechanisms requires a more distinct understanding of the distinctive features of the operation of these mechanisms.

Figure 1 presents a diagram of a ball mechanism with a semicircular tooth profile. The figure designations are as follows: 1, screw; 2, nut; 3, balls; α, contact angle in the normal section of the thread; λ, helix angle of the thread at the mean diameter (diameter of the location of the balls' centers); r, radius of the balls; R, radius of the circle of contact between the balls and nut, v_B, velocity of the screw; ω, angular velocity of the nut's rotation; v and $v_Г$, linear velocities of the center of the ball and point of the nut that is in contact with the ball; and C_1 and C_2, points of contact between the ball and the screw and nut. For specificity's sake, it is assumed that the nut turns and the screw is loaded with a downward-acting force moving forward and upward.

It is obvious that the line C_1C_2 of contact between the ball and helical surfaces of the grooves of the screw and nut do not lie in the mechanism's radial plane passing through its longitudinal axis. In the cross section A-A the projection of the line C_1C_2 forms some angle γ with the radius (OM) (O being the projection of the screw's axis) and $\sin\gamma = r/R \sin\alpha \sin\lambda$. When the nut turns, the balls

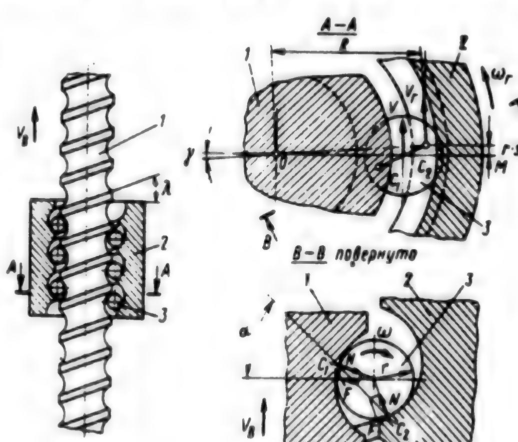


Figure 1

move in such a way that their centers in the projection A-A remain on a circle with a constant radius. Consequently, the projection of the velocity v is directed perpendicular to OM. The velocity of the point C_2 of the nut that interacts with the ball is perpendicular to the radius OC_2 and forms the angle γ with the projection of v. The velocity of the point C_1 of the screw is perpendicular to the plane A-A.

The three specified velocity vectors are linearly independent of one another. A consequence of this is the characteristic feature of screw-type ball mechanisms: the balls rotate around the axis coinciding with the direction of the motion of their centers. A transverse slide occurs in the contact. In reality, given any motion of the ball, the velocity of its center equals the half-sum of the velocities of diametrically opposed points on its surface, specifically, those points lying in the areas of contact C_1 and C_2. Owing to the linear independence, the velocity v of the center of the ball cannot be the half-sum of the velocities v_B and v_Γ. Therefore the velocities of the points C_1 and C_2 do not coincide with the velocities of those points on the ball that interact with them. The extent of the slide is proportional to the projection of the velocity v_Γ onto the line OM.

If there is no slide between the ball and screw (here, greater than the coefficient of sliding friction), then in the contact between the ball and nut the slide velocity equals $v_\Gamma \sin \gamma / \sin \alpha$ or $\omega_\Gamma r \sin \lambda$. If there is no sliding of the ball relative to the nut, then sliding is present in the contact between the ball and screw—and with the very same relative velocity. Finally, if the friction conditions in both contacts are identical, the ball rotates in a plane that is transverse to the direction of the motion of its center with an angular velocity of $\omega = \omega_\Gamma / 2\sin \lambda$, and sliding at a velocity of ωr is observed in both contacts. The resultant friction forces F displace the center of the ball (as is shown in Figure 1) in the cross section B-B. N designates the normal force in the contact. The direction of the rotation ω of the spheres and their displacement in the thread change when the direction of the nut's rotation changes.

As a result of the displacement of the balls under the effect of the friction forces there is a danger of extending beyond the contact regions on the edge of the thread and a reduction in the mechanism's operability. To avoid this, the following conditions must be met when designing reversing mechanisms:

$$(R_5 - R_3)/R_1 > 1 - \cos(\alpha + \rho)$$

and

$$(R_4 - R_6)/R_2 > 1 - \cos(\alpha + \rho),$$

where ρ is the friction angle, $\operatorname{tg} \rho = f$, f is the coefficient of sliding friction, R_1 and R_2 are the radii of the screw's and nut's tooth profiles, R_3 and R_5 are the inner and outer radii of the screw's thread, and R_4 and R_6 are the outer and inner radii of the nut's thread.

The efficiency of a screw-type ball mechanism is determined primarily by the losses to friction during transverse sliding of the balls. The magnitude of the friction forces acting in the contact between one ball and a screw and nut is calculated as the doubled (two contacts) product of the friction force times the slide velocity:

$$\Delta A = F\omega_\Gamma r \sin \lambda.$$

At the same time, the contribution of one ball to the completion of the useful work, i.e., the lifting of a load, equals the product of the axial component of the normal force times the velocity of the screw

$$A = N \sin \alpha \omega_\Gamma R \operatorname{tg} \lambda.$$

Consequently, the loss coefficient ν is approximately equal to $\Delta A/A = fr/R \sin \alpha$, and the mechanism's efficiency equals $\eta = 1 - \nu = 1 - [fr/(R \sin \alpha)]$.

For a 40 x 10 OST 2N23-7 gearing when $f = 0.1$, $r = 3$ mm, $R = 22.1$ mm, and $\alpha = 45°$, we obtain $\eta = 0.98$. The high efficiency is achieved by the low value of the transverse slide velocity: in the given case when $\omega_\Gamma = 10$ s^{-1} and $\lambda = 4.55°$, the slide velocity amounts to 1.2 mm/s or 1.1 percent of the velocity of the motion of the balls' centers.

Besides rotating around the axis coinciding with the direction of the motion, the ball of the mechanism rotates around the contact line C_1C_2 with an angular velocity equal to $\omega_\Gamma / s \sin \alpha \cos \lambda$. This turning, which is caused by the length of the real contact areas in a radial direction, causes additional losses to friction, but these are significantly smaller than the losses to friction during transverse rotation of the ball. The energy losses when the ball rolls in a plane with the trace C_1C_2 are even smaller. The situation is such that even though rolling predominates in screw-type ball mechanisms, the main energy losses and wear in them are caused by the sliding of the balls in contact with the screw and nut. Compared with that in a screw-slide nut gearing, the velocity of the slide in the joints is reduced $2R/(r \sin 2\lambda)$ times, which explains the high performance characteristics of screw-type ball mechanisms.

When designing and manufacturing screw-type ball mechanisms, correctly understanding the kinematics and sources of resistance to the motion of these mechanisms will facilitate an increase in the performability of the new developments.

UDC 621.9.048.6.06

Devices for Finishing Workpieces

907F0080I Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 17-19

[Article by N. I. Bondar, meritorious inventor of the UkSSR and candidate of technical sciences, and Yu. M. Samodumskiy, candidate of technical sciences under the "To Help the Process Engineer and Designer" rubric: "Devices for Finishing Workpieces]

[Text] The VU-19 vibration unit (author's certificate no. 1076266) is intended for finishing, hardening, cleaning, and grinding workpieces in an environment free of abrasive and metal and nonmetal fillers. Mounted on the spools of the base (1) (Figure 1) are springs (3) that have a table vibrator (4) mounted on their upper part. A toroidally shaped working chamber consisting of elastically connected fixed inner (6) and movable outer (5) rings is mounted on the latter. The rings are connected by an elastic coupler (8) in the bottom part of the chamber. The movable ring is made of separate sectors that are also joined by elastic material. The sectors of the movable ring are supported on the table vibrator by collars through removable elastic elements (9). The rigidity of the elastic elements is controlled by a screw and nut. An electric motor is mounted on the center of the base. It rotates an imbalanced vibrator (2) through a clutch.

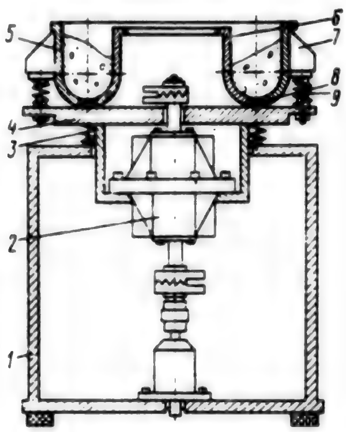


Figure 1

The workpieces and abrasive granules, metal balls, and rollers are loaded into the device's working chamber to which the motor transmits circular low-frequency vibrations. The table vibrator, which is mounted on springs, and the fixed ring of the working chamber vibrate with a frequency equal to the rotation frequency of the motor and with an amplitude that depends on the separation angle of the imbalanced weights of the vibrator.

Workpieces are machined during the process of a complex motion. It is rotary in relation to the longitudinal axis of the working chamber and forward along this axis.

The amplitude and frequency characteristics of the machining may be controlled by selecting the rigidity of the elastic elements (9) and controlling it by using screws. The entire moving system is a resonance system that effects resonance vibrations with an amplitude that is 1.5 to 5 times as large as the steady amplitude of the table vibrator's vibrations. The period of the natural vibrations of the entire moving system located on the table vibrator is established equal or close to the frequency of the electric motor's rotation.

Different values of the amplitude of the vibrations of the fixed and movable rings and all of the individual sectors may be obtained by design and by selecting the rigidity of the replaceable elastic elements (9), the mass of the unit's movable elements, and the magnitude of the perturbing force of the unbalanced vibrator. The nature of the change in the vibrations of each individual element may vary.

The rings and sectors move in the direction of the effect of the imbalanced forces. The movable ring and its sectors, which are joined with the fixed ring by an elastic element, effect a plane-parallel motion after the fixed ring (relative to the table vibrator): a motion that is forward in two mutually perpendicular directions (made together with the table vibrator) and a turning motion relative to the elastic coupling element (8) (made with a frequency equal to the frequency of the system's vibrations). The sweep of the vibrations of the outer movable ring and its sectors depend on the amplitude and frequency characteristics and rigidity of the replaceable elastic elements (9) and the material of the element (8).

The individual sectors of the ring (5) have a different type of vibrations. The cross section of the working chamber changes periodically during the period of each of the unit's vibrations on account of the turning of the elastically connected sectors of the movable ring relative to the elastic element (8). When the sector shifts to the center of the working chamber, the inner pressure increases in the mass of the load in the working chamber (and the relative friction increases), the productivity of the process increases, and the quality of the surface layer of the workpieces being machined improves.

During finishing operations on workpieces made of 45 steel, the metal removal increased by 80 to 82 percent, the duration of the machining process was reduced 1.6- to 1.7-fold, and the microhardness of the hardened workpieces (40 to 42 HRC) increased by 70-72 percent.

The VU-17 vibration unit (author's certificate no. 1030145) is used in finishing the surface of disk-type brittle workpieces. The container (8) (Figure 2) has a gate (9) that is secured on its axis and that turns by a flywheel with a catch and an incline slide with a bevel (10). An imbalanced vibrator (2), which acts on the container, is set into rotation by an electric motor (1).

The vibration unit's separator consists of a set of perforated cylinders (7) made of polymer materials or metal lined with rubber. The cylinders are made with inclined faces that have holes in them. The diameter of the latter does not exceed the minimal size of the workpieces being machined. Brushes (6) are mounted on the outer surface of the perforated cylinders along the helix. The direction of the helix is opposite for each of the adjacent cylinders.

The cylinders are equipped with shafts that are kinematically connected with the electric motor (5) by a belt transmission. The belts bend around the pulleys so that the cylinders turn in the direction of the arrangement of the brushes.

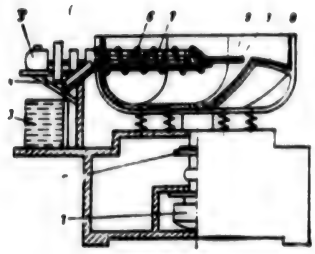


Figure 2

Guides ending in a sloped section (4) are located under the set of perforated cylinders. The intake container is filled with a viscous fluid (3) (glycerin, machine oil, etc.) to prevent the destruction of brittle workpieces.

The brushes are mounted on an elastic belt that is laid in the helical grooves of the cylinders. The helical grooves may be cut at several entries.

The working medium and workpieces are placed in the container. The imbalanced vibrator communicates low-frequency vibrations to the container and a helical motion along its cavity to the working medium and workpieces. During the machining process the mass of the load rises smoothly along the incline slide and descends along the bevel, and a turning gate gives it a closed motion.

After the end of the machining the turning gate is fixed horizontally. The ingredients loaded move along the incline slide and turning gate to the rotating perforated cylinders. The working medium penetrates through the face holes and into the perforated cylinders. It then returns to the container through radial holes. The level of working medium required to separate the remaining workpieces is kept constant.

The brushes grip the workpieces, place them vertically on guides, and transport them to the inclined section, from where they roll by themselves into the receiving device.

The unit makes it possible to machine, separate, and unload plane optical components with high productivity. Spalls and rough surface defects on the workpieces' surfaces are eliminated, and defective production is reduced by 40 to 60 percent.

The VTU-16 vibration turbulence unit (author's certificate no. 1030144) is intended for finishing, surface conditioning, cleaning, and hardening workpieces and for preparing them under a coating to remove surface stresses. It consists of a bed (2) (Figure 3) on which the following are mounted: an electric motor (1), a variable speed drive (3) and belt transmission (4), and rolling contact bearings for the main shaft (6), which is attached to a drive fork (7). Guides made of nonmagnetic material are mounted on the latter.

Mounted on the guides (by hubs that simultaneously serve as the poles of the electromagnets) are cups (10) with shock absorbers and coils (11) (secured by nuts). Rams (12) that are fashioned together with the spring

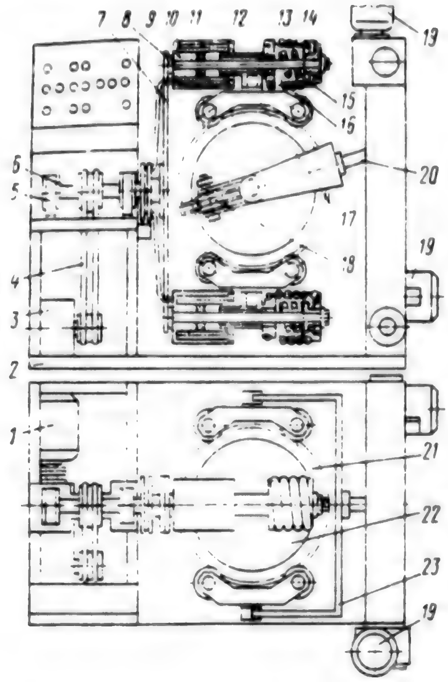


Figure 3

holders serve as movable cores of the coils. A threaded sleeve (14) that also has an outer thread (but with a larger pitch) to connect with the spring holder (13) is turned on the free end of guide.

The faces of the ram and threaded sleeve rest on the ground turns of the compression spring (15), which is encompassed from without by a large-diameter extension spring (16). The edge turns of the spring (16) are mounted on the spring holder of the ram and the spring holder (13).

Carriages (17) with rollers (18) that are mounted freely in axes are mounted in the rams' bores. The carriages with rollers hold a container (22) by two mutually perpendicular rings (21). One of the pairs of carriages is connected to a carrier (23) with an attached axle that enters (with clearance) into the four-way union of the frames and that moves with the help of horizontal and vertical lead screws that receive their motion from direct current motors (19).

Before the unit is switched on, the vibrating motion assembly must be prepared for operation. This requires turning the threaded sleeve (14) onto the threaded end of the guide, compressing the spring (15), and stretching the spring (16) to a force equal to that required to move the loaded container along the guides.

After the end of this operation, to set the container into a vibrating motion it is sufficient to apply a small (in magnitude) periodically changing perturbing force to the ram-core. The electromagnetic field of the coils, which are fed a pulsed current, specifies this force.

The container receives a rotating motion from the main shaft. A pulsed current is fed to the coils (whose magnetic field attracts the ram-core) from a control panel through the brushes and collector rings (which are connected to the main shaft). After the effect of the electromagnetic force has ceased, the spring (16) returns the ram to its initial position, i.e., the container receives a vibrating motion in a horizontal plane through the carriage rams and rollers.

To intensify the process and increase the machining quality a mechanism has been provided to control the spatial motion of the container. It consists of a carrier with an axle (20) that enters the opening of the frame's spider. It is capable of turning relative to two mutually perpendicular axes (the axis changes its position in space, which provides the different versions of the container's complex motions).

The vibration exciter (author's certificate no. 1102634) (Figure 4) is intended for use in vibration units. A drive shaft (4) with a hub (6) is connected (by means of elastic elements (2)) to the rim (1). Two imbalanced chambers, each of which is in the form of two branches (7), are connected by flexible pipes (5). An imbalanced mass in the form of balls (8) is loaded into the branches.

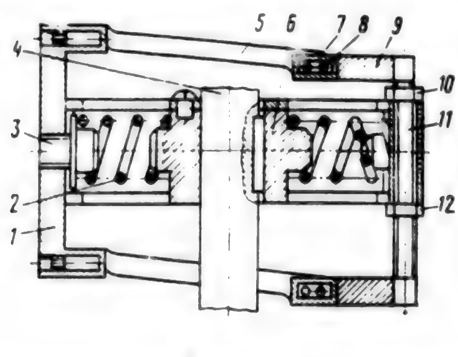


Figure 4

Branches lying close to the axis of the shaft's rotation are mounted with the capability of axial movement. A threaded connection of the console (9) with a rod (11) passing through the opening into the rim is provided for this purpose. Nuts (10) and (12) fix the rod. The slope of the flexible pipes is controlled by these nuts. To increase the smoothness of their operation, the imbalanced chambers are filled with fluid.

When the balls move in the branches, the rim's gravity center is displaced. This creates a perturbing force that deforms the elastic elements (2) and moves the rim relative to the drive shaft's axis. The imbalance caused by the rim's displacement adds to the imbalance caused by the movement of the balls in the branches.

When the drive shaft is disconnected, the balls return (by the force of gravity) to their initial position as the frequency of the drive shaft's rotation and, consequently, the centrifugal force decrease. Elastic elements (2) eliminate the rim's imbalance.

The number of balls or the preliminary stiffness of the springs (by using screws (3)) is changed to control the amount of imbalance.

The fluid in the imbalanced chambers increases the smoothness of bringing the vibration exciter to its operating mode. As a ball moves, the centrifugal force moving this ball increases in proportion to the distance to the rotation axis, whereas the force of the fluid's resistance changes while the pipes' cross section remains constant.

To compensate for the increase in centrifugal force it is possible to use pipes with a variable cross section, for example, one that decreases evenly in the direction to the branch that is farthest from the rotation axis. In such pipes the resistance of the fluid acting on the ball increases evenly in proportion to the remoteness of the ball from the rotation axis, and this ensures smooth entry into the operating mode.

The vibration exciter makes it possible to automatically achieve a specified amount of imbalance and provides smooth entry into the operating mode and braking with different values of the vibration machine's resonance frequency, thereby expanding its technological capabilities and increases its reliability.

UDC 621.983.7.044.7

Magnetic Discharge Assembly by Reducing Swing Assembly of Hydraulic Machine

907F0080J Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 19

[Article by I. D. Balon and A. B. Luchko]

[Text] The swing assembly of piston hydraulic machines, which consists of a cylindrical-barreled piston with a ball bearing and a thrust bearing with a skirt that is flared onto a ball bearing, experiences cyclic stretching loads. The force of the opening of the thrust bearing's flared skirt is between 0.05 and 0.1 kN with a frequency to 20 Hz over 5,000 to 6,000 hours of continuous operation.

During the conventional method of assembling the swing assembly, complete contact of the surfaces of the ball bearing and thrust bearing is lacking. In addition, it is necessary to uncoil the thrust bearing's skirt after the flaring to create the required axial play in the swing assembly's joint. This operation is implemented manually by a roller tool on a universal lathe, which reduces its quality and does not provide stable axial play. (There are cases where uncorrectable defective production is produced after the uncoiling.)

These shortcomings of the conventional assembly method result in a reduction of the useful life of the swing assembly owing to the rapid increase in axial play.

As a result the hydraulic losses increase, and the hydraulic machine's volumetric efficiency is reduced.

A progressive technology for magnetic discharge assembly by reduction of the swing assembly of a hydraulic machine has been developed. An experiment was conducted with the swing assemblies of 50NR32 pumps manufactured by the Kharkov plant Gidroprivod. The material of the piston (5) (Figure 1) was ShKh15 steel, and that of the thrust bearing (3) was BrAZh-9-4 bronze. An MIU-20 magnetic discharge unit with a universal field structure was used. A magnetic field concentrator (1) mounted on an MIU-20 universal field structure and dielectric pads (2) and (4) were manufactured for the test operations. The multipulse mode of magnetic discharge assembly by reduction that was selected resulted in nominal axial play (0.03 to 0.04 mm). The swing assemblies produced by magnetic discharge assembly by reduction and those obtained by the conventional method were tested on a model R-20 tearing machine with an attachment to fix the piston and thrust bearing in the machine's live zone. The results of the experiments showed that the breaking force of the swing assembly assembled in the conventional manner amounted to 5.8 kN whereas that produced by magnetic discharge assembly by reduction amounted to 5.4 kN. The variance in the size of the breaking force of the swing assembly was 0.3 and 0.15, respectively, which is confirmed by measurement of the axial play in these assemblies immediately after the assembly. The deviation from the normal amount came to plus or minus 25 percent for the swing assemblies manufactured by the conventional method and ranged from -5 to +10 for those produced by magnetic discharge assembly by reduction. Sectioning several thrust bearings assemblies by the new method showed that virtually complete contact of the surfaces of the skirt and ball bearing is achieved. This reduces the specific pressure on the inner surface of the thrust bearing's skirt and increases the capacity to resist cyclic loading.

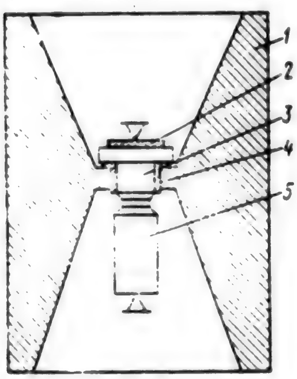


Figure 1

The progressive technology of assembling the swing assembly of a piston hydraulic machine makes it possible to increase the precision and stability of assembly with respect to the amount of axial play, which improves the operating characteristics of hydraulic machines, eliminates the operation of uncoiling, eliminates the possibility of obtaining a defective product, and increases the degree to which the assembly process is automated.

The proposed yearly economic effect from introducing magnetic discharge assembly by reduction for the swing assemblies of type 50NR32 pumps at the Kharkov plant Gidroprivod will amount to about 8,500 rubles.

UDC 576.8.093.36

Anaerobic Sealants for Fixing Components

907F0080K Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 19-20

[Article by E. B. Fomenko and V. D. Khvorostova]

[Text] Anaerobic sealants are currently finding application in the creation of machines, devices, and structures operating under conditions of high speeds and high temperature and pressure differentials. They are used to contain and seal threaded and cylindrical connections and flat connectors and to impregnate porous castings.

Liquid anaerobic products that are self-hardening in the narrow gaps of components that are being joined in any configuration seal the assemblies of machines with a high degree of leak tightness. In addition they fix components that are arranged relative to one another, i.e., they create the required mechanical bond.

Bearings and bushings are mounted in an aluminum case by using a pressed fit, transitional components, check rings, and pins, which requires expensive machining with narrow tolerances and pressing equipment. In the case of a pressed fit, inadequate contact between the metal surfaces of components owing to very small irregularities frequently causes bearings to undergo "fitting corrosion," which is a consequence of the penetration of air and moisture into the gaps.

By using anaerobic sealants it is possible to fix the joints of cylindrical metal surfaces with a sliding fit. By filling the space between the components with a stiff film that is resistant to the effects of aggressive media and that ensures 100 percent contact of the surfaces, anaerobic sealants increase the joint strength and improve the smoothness of the assembly's operation. They possess a set of properties: adhesion and resistance to water, oil, lubricants, motor fuels, organic solvents, acids, alkalis, and many other chemicals. Using anaerobic sealants makes it possible to reduce the labor intensity of manufacturing, the specific consumption of metal for a structure, and the toxicity of production.

To determine the optimum parameters of cylindrical joints (D, diameter of the component at the site of contact; l, length of the contact surface) during fixation by different grades of anaerobic sealants, research was

conducted on the dependence of strength τ_{gb2} during axial shift on the size of the gap between the components being joined.

Three holes 80 mm in diameter with tolerances ensuring gaps of $a_1 = 0.08$ mm, $a_2 = 0.14$ mm, and $a_3 = 0.18$ mm during configuration of the outer ring of a No. 208 bearing were made in an aluminum plate that was manufactured from the alloy AL-5. The gaps were selected by proceeding from the condition of ensuring the coaxiality of the components so as to avoid additional imbalance and also from the condition that the radial play of the bearing itself not be exceeded. The actual size of the gap Δ between the surfaces being joints equals half the gap a.

Three grades of second-generation sealants with a high shift resistance in this gap range became the research objects: UG-7 (viscosity, 100 to 200 centipoise; strength during axial compression, 15 MPa; and maximum actual recommended gap, 0.15 mm); UG-9 (600 to 1,000 centipoise, 15 MPa, and 0.3 mm); and AN-6K (15,000 centipoise, 20 MPa, 0.4 mm).

When joints were assembled, the hermetic sealant was applied by brush from the dropper of a standard small bottle onto the surfaces of the components that were being joined and was subsequently distributed by using the brush. Two methods were tested: the first entailed applying the sealant onto the surface of one of the components being joined, and the second entailed applying the sealant onto the surface of both components.

Twenty-four hours after the assembly, the strength of the joint was measured during axial shift at a speed of 10 mm/mm on a UMM-1 universal testing machine that measures a load with an error of 1 percent the measured quantity. The tests showed that the strength properties of the joint produced by the first method were somewhat lower than that those of the joint produced by the second method. Therefore, when more joints were assembled, sealant was applied to the surfaces of both components being joined.

The strength during axial shift was calculated in accordance with the formula $\tau_{\beta 2} = P/S$, where P is the maximum force of the shift in kilograms force and $S = \pi Dl$ is the adhesion area in square centimeters.

Graphs of the strength τ_β of the joints as a function of the size of the gap Δ and the viscosity of the anaerobic sealant were plotted (Figure 1).

The curves of the dependencies for the three grades of sealant are identical in nature, which makes it possible to calculate a generalized coefficient K of joint strength as a function of the gap. The coefficient K was calculated as the arithmetic mean of the experimentally obtained ratios of the strength during axial shift to the maximum value of the strength threshold in the specifications for the respective grades of sealant. Figure 2 graphs the coefficient K as a function of the gap size Δ.

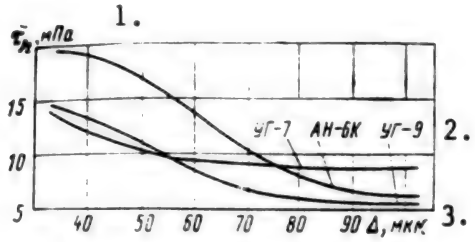


Figure 1

Key: 1. MPa 2. UG-7; AN-6K; UG-9 3. Δ, μm

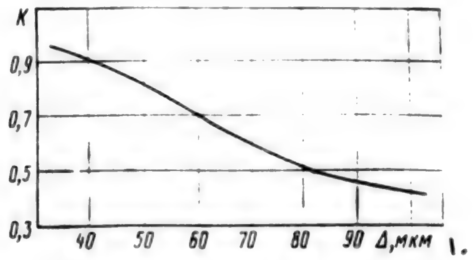


Figure 2

Key: 1. Δ, μm

The resultant dependence makes it easier to predict the strength of a joint of cylindrical components when an anaerobic sealant is used and easier to select the gap size and grade of sealant in accordance with the required joint strength, which is necessary when switching from conventional methods of locking cylindrical components to fixing them by using anaerobic sealants.

The anaerobic sealants are polymerized throughout the entire range of gaps recommended for the given grades. However, to obtain the maximum strength characteristics of cylindrical joints it is most advisable to select the actual gap in the range from 0 to 50 μm, which corresponds to gaps with a diameter between the joined components that is between 0 and 100 μm.

UDC 621.923.6;621.923.5.02:621.033.052

Gear Shaving With Increased Product' 'ity

907F0080L Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 20-21

[Article by M. I. Olifirenko, candidate of technical sciences, V. M. Stolyarov, and V. V. Savchuk]

[Text] Shaving increases the degree of gears' precision and improves the roughness of the teeth's flanges. The process is not very productive, however. Products having a surface hardness of more than 32 HRC are not generally shaved since the existing shaver designs are not workable, i.e., they do not remove metal even with increased contact loads since their cutting edges lack feasible end-clearance angles.

A standard shaver contacts a tooth's flange along a margin 1 to 2 mm wide that scrapes metal particles from the surface during the reciprocal motion along the axis of the tool and workpiece. In a similar case, the necessary condition of removal of the metal may only occur in the case where the "sliding strip" deforms the metal to some depth. In other words, the cutting conditions will be very ineffective from the standpoint of the theory of cutting metals since it is not a wedge but rather a plane surface in the form of a margin that will be introduced into the metal.

The essence of the proposed method of relieving (author's certificate no. 1220741) lies in sharpening the edge of the shaver's tooth as if it were a margin and having it work like the edge of a conventional cutting tool with an angle on its flank that is positive with respect to the tangent of the radius at the cutting point.

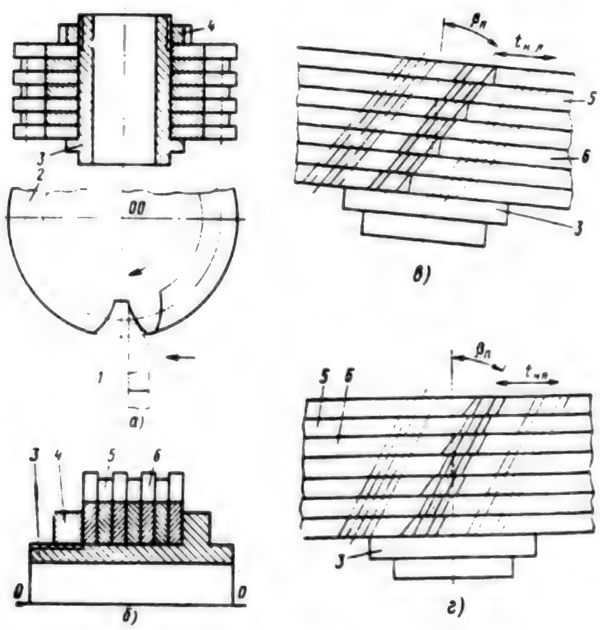


Figure 1

The method of creating a positive angle on the flanges of a shaver's teeth consists of having the shaver (2) (Figure 1a) manufactured as an assembled piece consisting of working and intermediate disks. The disks are mounted on a bushing (3) and fixed by a clamping ring (4), thereby making it possible to change the spiral's slope by turning the working and intermediate disks around the axis and fixing them in the required position. Before the relieving the disks are shifted along the spiral with different pitches for the left and right flanges of the shaver's tooth. The amounts of these shifts are expressed by the following equations:

$$t_{norm.\ l} = t_{norm}(\cos\beta/\cos\beta_l)$$

and

$$t_{norm.\ r} = t_{norm}(\cos\beta/\cos\beta_r),$$

where $t_{norm.\ l}$ and $t_{norm.\ r}$ are the normal pitch on the shaver's pitch circle during relieving for the left and right flanks, respectively, of the shaver's teeth (Figures 1c and 1d); t_{norm} is the normal pitch on the shaver's pitch circle; β_l is the slope of the helical surface of the shaver's tooth during alignment for shaving; β is the slope of the helical surface of the shaver's tooth during alignment for relieving the left flank of the shaver's teeth (Figure 1c); and β_r is the slope of the helical surface of the shaver's tooth during alignment for relieving the right surface of the shaver's teeth.

Figure 1c shows the position of the working disks aligned for shaving the left side of a shaver's teeth, and Figure 1d shows the position of the working disks aligned for relieving the right side of a shaver's teeth. Figure 1b shows the working disks adjusted for shaving.

A disk shaver is relieved on gear-grinding equipment by a grinding wheel (1) (Figure 1a) while the latter moves forward along the shaver axis OO and while the shaver rotates accordingly around this axis. The right and left side of the shaver are ground separately independently of one another.

To machine the left side of the spiral of a shaver's teeth, the clamping ring along the bushing's thread is unscrewed, the disks (5) and (6) are released (Figure 1b), and they are turned relative to the bushing axis at the angle β_l (Figure 1c). The position of the working disks and their configuration are checked against a standard on parallel axes, after which it is fixed with a clamping ring. The grinding machine's change gears are aligned with respect to $t_{norm.\ l}$ and $t_{norm.\ r}$. The alignment for relieving the right flank of a shaver's teeth is implemented analogously (Figure 1d).

Tests of a shaver relieved in accordance with this method showed that the productivity of gear shaving increased 1.3- to 1.5-fold, with the precision of the machined products having a quality of 5 to 6 (m = 6 mm, z = 141). It became possible to increase the hardness of the teeth of machined gears by 5 to 6 HRC units, which increased the machined products' service performance.

The yearly economic effect from introduction at only one enterprise amounted to 30,000 rubles.

UDC 658.52.011.56.912.3.005;658.563.011.56;621.0.02-539

Tool Support for FMS

907F0080M Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 21

[Article by V. A. Nesterov and A. V. Baykov]

[Text] A plan (its technical organization part) of a section for aligning a tool outside an FMS (flexible automated line) for machining reducing gear bodies has been developed at the Donets Planning, Design, and Technological Institute.

The section is a structural component of an automated tool support system, and it performs the following tasks:

—ordering and receiving tools from a central tool warehouse;

—storing and keeping track of tools;

—assembling, aligning, and completing tool setups in accordance with standard equipment charts;

—disassembling a setup that has been used;

—performing intake and ongoing monitoring of tools' quality and precision;

—sending a tool for sharpening and repair;

—scheduling tools;

—sending information about a tool's motion and the provision of tools at workstations to the control computer complex.

The flexible automated line's yearly and monthly demand for cutting, auxiliary, and measuring tools is calculated on the basis of the planning and accounting program for the manufacture of components. These data are the source data when calculating the number of instruments for aligning tools away from the machine tool, the number of workers in a section, and the makeup and amount of office facilities, devices, and equipment.

From an organizational standpoint, the section consists of four structural subdivisions: the tool storage and completion section, the tool assembly/disassembly and alignment section, an inspection and testing station, and a storage unit for aligned tool sets (the latter are needed owing to the absence of a link between the section and the automated transport and warehousing system owing to the configurational features of flexible automated lines.

The section's workers are united into one brigade. Flexible distribution of functional duties among the brigade members is suggested: combination of occupations and interchangeability of workers in the event of an unforeseen situation.

To achieve failure-free operation of the tool alignments, the forced replacement of a tool before the expiration of its guaranteed durability period (calculated with an allowance for the probable nature of wear at a reliability level of 0.9) has been introduced. The norms for storing a cutting tool in a section exclude any downtime of the flexible automated line.

The plan presents the informational and material links between the section and the systems supporting the functioning of the FMS and the plant's subdivisions.

The anticipated yearly economic effect from introducing the plan amounts to 15,000 rubles.

UDC 621.793.182

Electrospark Alloying Sharp-Edge and Stamping Tool

907F0080N Moscow MASHINOSTROITEL in Russian No 9, Sep 89 pp 21-22

[Article by V. I. Shemegon and M. V. Zhuk]

[Text] To increase the wear resistance of single- and multiedged cutting tools and that of the components of stamping equipment, the method of applying wear-resistant coatings onto their working part is currently being used.

The Khabarovsk Naval Service and Operations Base and Automotive Plant work is underway on the electrospark alloying of spiral bits, end milling cutters, and shearing punch and die sets made of the steels R6M5, R6M5K5, R9K5, NSS, R6M5F3MP, U8, U10A, and Kh12M.

The electrospark alloying was implemented on Elitron-10 and EFI-54A units in the first mode.

The hard alloys T15K6 and VK8 were used as the material for the alloying electrode (anode) for the electrospark alloying. The alloy T15K6 was used to alloy spiral bits 6 to 14 mm in diameter, and the alloy VK8 was used to harden the punches and dies of shearing punch and die sets and end milling cutters 8 to 25 mm in diameter.

The spiral bits were alloyed with subsequent polishing of their helical grooves to produce a surface roughness of $Ra = 0.32$ μm.

The end milling cutters were alloyed along the shanks of their face teeth on the main cutting edge and along the margin of the cylindrical surface for a length of 20 mm.

The punches of the shearing punch and die sets were alloyed along the face. On the dies a band 5 mm wide along the perimeter of the window was subjected to alloying.

Production tests showed that the contact surfaces of the alloyed tools wear out much more slowly than do those without coatings. When drilling through holes in blanks made of the steels St3, 45, U8, and 12Cr18Ni10Ti, the durability of the spiral bits increased between 1.33- and 2.3-fold. When blanks of the steels St3 and 40 were machined (after being cutting out on a flame cutter), the durability of the end milling cutters increased between 1.5 and 2 times. When blanks were produced from St3 steel 3 mm thick and nonferrous alloys 0.5 to 0.8 mm thick, the durability of the shearing punch and die sets increased between two- and threefold when compared with the durability of nonalloyed tools. Lubricating and cooling equipment was not used in the machining. A complete loss of cutting properties characterized by the appearance of squeaks was used as the wear criterion for the spiral bits, destruction of the cutting edge of the teeth and a total loss of operability were taken as the criteria

for the dulling of the end milling cutters, and an increase in the burr along the edge of the blanks was assumed as the wear criterion for the shearing punch and die sets.

The durability of the contact surfaces of spiral bits, end milling cutters, and shearing punch and die sets after electrospark alloying increases thanks to a change in their physical, chemical, and mechanical characteristics. Specifically, after electrospark alloying the microhardness of the contact surfaces ranges from 1,072 to 1,824 N, whereas that of spiral bits of R6M5 steel without coatings ranges from 724 to 870 N. The coating contains α-Fe, WC, and TiC phases, and the surface relief consists of silver-colored spherical segments. The coefficient of the friction on the contact surfaces is reduced, as a result of which the adhesion of the material being machined decreases and the removal of chips from the cutting zone improves. The intensity of diffusion wear (during which the concentration of carbon in the steel's martensite is reduced, which results in a significant reduction in its hardness) is partially reduced.

Using electrospark alloying to increase the durability of spiral bits, end milling cutters, and shearing punch and die sets makes it possible to improve the provision of tools at machine tool operators' workstations; increase their labor productivity by reducing the time required to remove, resharpen, and configure tools; and significantly reduce the consumption of expensive tool materials.

The economic effect from introducing electrospark alloying of tools amounted to 42,000 rubles.

UDC 621.7.025.06

Degreasing Unit for Bar Stock

907F0080O Moscow MASHINOSTROITEL in Russian No 9, Sep 89 p 22

[Article by P. A. Sadov]

[Text] The Novosibirsk affiliate of the Orgstankinprom Scientific Production Association has developed a unit to degrease bar stock (author's certificate no. 1192869).

The device consists of a frame (1) (Figure 1a) on which the following are mounted: a vat (3), a tank (2), a pump unit, and an electric drive for mechanisms to roll bars over and transfer them.

The sprockets (6) and (9) of the rolling mechanism are attached to shafts (7) and (8). The latter is connected to an electric drive. The sprockets (4) and (12) of this mechanism are mounted freely on shafts (5) and (11). A chain (10) encompasses all these sprockets. The shafts (7) and (8) and (5) and (11) are connected in pairs by chains. The bar-loading mechanism is connected to roll the bars over and is formed by shafts (5) and (11) with paris of sprockets (13) and (19) (Figure 1b) mounted on them as well as by shafts (7) and (8) with pairs of sprockets (15) and (17) that are mounted on them with the capability of moving. The chains of the transfer mechanism, the ends

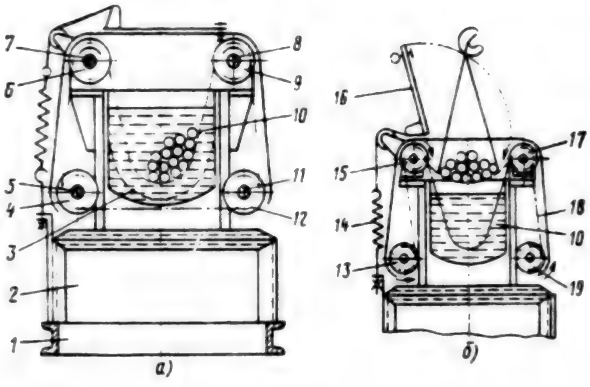


Figure 1

of which are secured on sprockets (13) and (19), are transferred through the sprockets (15) and (17).

The chains of the transfer mechanism are immersed into the vat and released, leaving the bar stock on the chains (10) of the mechanism to roll the bars over. The electric drive is automatically switched off. The cover (16) closes, the gear box switch is moved to the wash position, and the electric drive is turned on again. The bars undergoing the treatment are rolled over on the chains (10) of the rolling mechanism and cleaned to remove contaminants. After the washing has been completed, the electric drive is automatically switched off, and the cover is raised by a spring mechanism (14). The gear box switch is moved to the unload position. The chains (18) wound on the sprockets (13) and (19) raise the treated bars.

Material with a mass of 500 kg can be loaded. Bars with a length between 2 and 5 m may be treated.

The unit has a productivity of 1,000 kg/h. The mass including the washing solution amounts to 3,600 kg. Its overall dimensions are 6,250 x 1,300 x 1,500 mm.

UDC 658.310.627

Features of Development of Lease Arrangements at Enterprise

907F0080P Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 5-7

[Article by D. Yu. Prokofyev, candidate of economic sciences, under the "Steps in Perestroyka" rubric "Features of Development of Lease Arrangements at Enterprise"; first paragraph is MASHINOSTROITEL introduction]

[Text] Several years ago under conditions of the administrative system at an enterprise it was not necessary to address the theoretical foundations of production management or economic analysis of industrial relations since not only general matters but many specific ones as well were handled by the ministry. For this reason, enterprises are now forced to independently substantiate the new management methods that they are introducing.

The author of the article published below, D. Yu. Prokofyev, is the deputy head of the department of technical and economic research at the Moscow Electric Lamp Plant Production Association. He presents a critical examination of approaches to organizing the lease form of labor by analyzing the experience that has been accrued in introducing elements of lease arrangements in the individual subdepartments of the given enterprise.

The absence of clarity in defining the essence of lease arrangements in production leads to a situation in which in practice the leasing of an enterprise by a labor collective is essentially a modification of the second form of full cost accounting. Development of lease principles is, in our view, impossible without analyzing production resource ownership arrangements under conditions of socialist management. The contradiction is that it is the public itself that is the owner of the production resources and each individual worker involved in the production process, like the collective owner, requires specific forms of his own authorization.

The Law Governing the State Enterprise (Association) establishes the right of the labor collective as management to use the public property. However, this policy must find specific forms of implementation, and lease arrangements may become one of its forms.

When defining the essence of lease agreements it is above all necessary to specify the lessor who acts as the owner of the leased resources. As specified in the Law Governing the State Enterprise, the labor collective is such an owner. From the standpoint of the enterprise as a whole, it is the local, kray, republic, or all-union organs of power (depending on the given enterprise's level of subordination) that, as the lessors, step forth from the face of society as its legal representatives or owners of the production resources.

In our view, lease agreements imply that, as the temporary owner of the production resources, the lessee has the right to make an independent decision regarding the use of the leased production resources (for example, the kind of product and the volume in which it will be produced). However, under the conditions of the socialist market, where an enterprise's activity is above all based on the state plan, production geared toward a government order should be more advantageous for the enterprise. In this case a system of measures in the area of price formation, production finance, and product marketing may provide an advantage for production.

The nature of lease agreements assumes exclusively economic measures of action on the lessee when an agreement is reached. Consequently, the collective should retain the right to refuse to accept obligations regarding fulfilling a government order, or at the minimum, it should be afforded the possibility of having some influence on the size of this order as regards the total volume in which the product is produced. Therefore, before deciding to transfer a state enterprise to operation under lease conditions it is necessary to determine the goals and tasks that must be set for it by society, including in regard to its specialization in the manufacture of products.

In our view, the principles that are the basis for production in accordance with the currently operating "Policy on the Economic and Organizational Foundations of Lease Arrangements in the USSR" (adopted by the USSR Council of Ministers on 7 April 1989 [No. 294]) and the general methodological policies regarding the leasing of a state enterprise by a labor collective (developed by the Economics Scientific Research Institute of the USSR State Planning Commission [Gosplan] and the Finance Scientific Research Institute of the USSR Ministry of Finance) only partially conform to the principles of leasing despite reaching an agreement regarding leasing.

The lease form of management, which has recently been developed, differs from the second form of full cost accounting only by virtue of the fact that the leasing collective has the right to independently determine the size of withholdings to the social development fund, the production and science and technology development fund (within the limits of the absolute sum established by the enterprise), and the labor wage fund. Otherwise the conditions of an enterprise's activity, including the procedure for distributing income, generally remains unchanged and does not depend on whether the deductions from the enterprise's income to the higher-ranking organization are made in the form of fixed payments or in accordance with the norm.

It should be noted that the procedure of distributing income remaining at the enterprise's disposal that has been adopted in the given form of lease agreements does not in any way increase an enterprise's responsibility for the results of its activity in the area of introducing scientific-technical progress even though it assumes expanding enterprises' rights to use this income. What is more, under conditions of a deficit, the dictates of the producer, and his monopolistic position in the market, there is a real threat of a reduction in product quality and a reduction in the pace at which scientific-technical progress is introduced. This is connected with the fact that, under such a form of leasing, there are neither external nor internal stimuli to significant improvement of production. Nor are there any restrictions on using all of an enterprise's resources for end consumption besides the enterprise-established normative relationship between the growth of labor productivity and the growth of the average earned wage. Complications in the material and technical provision of capital investments and in specifying the contractor to conduct construction and erection operations introduce additional constraints on using assets within the framework of the social development fund and the fund to develop production and science and technology.

At the same time, the lease form of labor organization is undoubtedly progressive, and introducing it—even on

the basis of the principles established by the aforementioned policies—may bring perceptible positive results in low-profit industries. In our view, introducing the lease form of management into industry on a wide scale requires a number of changes in these methodological policies. Allowances must be made for constraints related to the current state of the national economy and the directions of its future development. Since the lease form of management, like any other new form, cannot objectively be introduced in the form in which it is possible in a system with a debugged economic mechanism, when we refer below to perfecting the lease form of management, we will be referring to its transitional form.

At the present time, a labor collective may reach an agreement regarding leasing a state enterprise on a three-party basis. In addition to the enterprise's labor collective and the higher-ranking organ of power, the higher-ranking administrative organization (ministry) enters into the agreement as a third party. Thus, an agreement with a ministry consists partly of a state order that includes the conditions of its provision on the part of the ministry and partly of a procedure for withholding from an enterprise's income funds for the ministry to implement its branchwide technical policy. Such a procedure is most effective if it is constructed on a full cost accounting basis.

It has been established in the general methodological policies regarding the leasing of a state enterprise by a labor collective that the rent payment is a portion of the receipts (in absolute sum) that has been previously established in an agreement with the higher-ranking organization and that is recalculated by it at stipulated times. The rent payment includes withholdings (in substantiated sums) for the centralized funds and reserves of the higher-ranking organizations for their upkeep and to accomplish branchwide tasks depending on the residual value and technical level of the fixed capital being leased and the amount of working capital turned over for temporary use with an allowance for the enterprises' profitability (unprofitability), the prospects for their development, the demand for the product they produce (or services they render), the features of their material and technical supply, and other objective factors in the rent payment. It is, however, necessary to refine the procedure for determining the rent payment that has been established by the methodological policies.

It is specified in the Law Governing the State Enterprise that an enterprise has the right to possess, use, and dispose of all of the assets on its balance sheet and that it may surrender buildings, facilities, equipment, vehicles, inventory, raw materials, and other materials of value for rent. The rent payment received is sent to the fund to develop production and science and technology. This is particularly important because when rent payments are directed to other funds (for example, the material incentive or social development or wage funds), the lessor, being the owner of public production assets, receives the right to use incomes that it did not earn.

This policy remains in force both in the relationships between individual enterprises and between enterprises and higher-ranking organizations and in relationships within an enterprise. The statement that withholdings for the upkeep of the higher-ranking organizations should be included in the rent payment is thus illegitimate. In truth, the conditions of a lease agreement generally stipulate the obligations of lessor (the higher-ranking organization) to provide the lessee with funds for raw materials, materials, and technology. It may (on an agreement basis) provide the lessee with assistance in retooling, training personnel, etc. In this case the lessor has the right to receive additional income, which may be agreed upon under the conditions of the agreement. However, this income is not, by virtue of its nature, connected with the rent payment.

In our view, further development of the lease form of management and modification of an enterprise's activity based on the first and second forms of full cost accounting should proceed in the direction of a transition from payment to funds and labor resources for taxation of income independently of whether a fixed rent payment will be levied. Primary attention should be focused on the stimulating function of tax. A system of tax advantages for incomes directed toward modifying production will make it possible to partially avoid the aforementioned shortcomings of lease arrangements that are connected with a lack of interest in introducing scientific-technical progress.

The mechanism for stimulating scientific-technical progress when switching to a lease should be developed with an allowance for who will receive production resources for rent and in what time frame. If the lessee is a collective of the enterprise that continues to use the resources before the agreement has been concluded and after it has ceased to be in force, then regardless of the time frame for which the agreement has been concluded, the lessee is the party that is most interested in increasing the technical level of production and expanding it. If an enterprise's production resources are surrendered for rent to a side organization or to individual workers under the assumption that the agreement will not be reached again and the term for which it is in effect is not very long, then the obligation (and this means financing production including expanding and modifying it) remains with the lessor. If, during the course of the time for which the agreement is in effect, a portion of the fixed assets are refunded owing to shared payments of the lessee or new assets are introduced, then, according to the conditions of the agreement, they must be repaid.

Speaking of the structure of rent payment, it should be noted that, in our view, there should not be any new deductions from income if the enterprise collective acts as a lessee and leases production resources that it already owns in conjunction with the Law Governing the State Enterprise. It is no accident that at the present time the sum of fixed payments to the budget and higher-ranking organization based on the five-year-plan indicators are generally accepted as the rent payment. At the same

time, if an enterprise's collective surrenders a portion of its fixed assets to a side organization or to individual collectives of the enterprise's subdepartments for the lease, then the structure of the rent payment should include an allowance for the depreciation deductions for full restoration and major repair as well as for the profit directed toward expanded reproduction. This will permit the enterprise to implement an independent technical policy regarding fixed assets surrendered for rent.

With regard to an additional increase in rent payment, for example, by the sum of the profit that an enterprise could make had it had independent use of the fixed assets transferred to lease, the given policy is not mandatory but may be adopted (by agreement of the parties), in which case the condition of the purposeful direction of the resources obtained by the lessor to the fund to develop production and science and technology should be observed. In addition, the rent payment collected from the individual subdepartments within an enterprise may also include a portion of the resources sent to the social development fund since the same rights to social support that exist in the enterprise's other subdepartments should be preserved for those workers in the subdepartments operating under lease conditions.

A mandatory condition of switching to a lease is the development of stable prices for the finished product produced by the lessee (if there were none before the switch to a lease). In view of this, the aforementioned elements of the rent payment may be included in it if they are also considered in the price structure.

The question of planning the normative relationship between the pace of the growth of labor productivity and the average earned wage should be answered when an enterprise switches to a lease. Despite its positive role (for example, in regard to restricting the overflow of an enterprise's entire income to the labor wage fund), this question introduces a number of important constraints to introducing a lease. Like the second form of full cost accounting, the lease form presupposes the formation of the given fund in accordance with the residual principle, where economizing on material expenditures has a direct influence on its increase. However, in the case where the production volume and number of workers remain stable but the labor wage fund increases on account of resources obtained by economizing on material expenditures, the normative relationship breaks down. Resources from saving on material expenditures can hardly be used as an incentive for workers.

This constraint impedes an enterprise's transition not only to operation under lease conditions but also to the second model of full cost accounting because changes in the system of full cost accounting relationships at the enterprise level may lead to perceptible results only in the event of respective changes in the system of in-plant full cost accounting. At the same time, various principles of forming the labor wage fund at the enterprise level and within it when its subdepartments switch to operation under the conditions of the second model of full cost accounting or a lease without the entire enterprise as a whole switching to these conditions may result in a breakdown of the normative relationship or in a discrepancy between the wage fund sums by subdepartment and the total sum formed with respect to the enterprise as a whole.

Thus, the spread of the lease form of full cost accounting is currently being held back by a number of constraints. In view of this, the decision to introduce it in the internal subdepartments of an enterprise should, in our view, be based in each case on an analysis of the individual subdepartment's operating conditions. At the same time, many forms of full cost accounting that have become traditional (for example, full cost accounting brigades and sections, the collective contract) may have a greater effect than does a lease depending on the specific features of an individual industry.

The advantages of the lease form of full cost accounting (expanding rights in distributing income, using progressive forms of rewarding and paying labor) may be used to modify the second form of full cost accounting. Moreover, developing the traditional forms of full cost accounting relationships will make it possible to avoid the disinterest in introducing scientific-technical progress having a long cost recovery period that is inherent to lease arrangements.

UDC 531.7.08

Testing Equipment in Automated Production

907F0080Q Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 11-14

[Article by Ya. B. Krutik]

[Text] The Kharkov Engine Building Production Association Sickle and Hammer has launched the operation of an automated shop to produce crankshafts for an SMD-31 engine, which is intended for completing combines in the Don series. The shop includes a system of automated lines for machining and heat treatment. The lines are connected in an automated flow by an interline transporter. Besides being equipped with machine tools and transport equipment, each automated line also has all of the equipment needed to monitor the linear and angular dimensions of a crankshaft and the deviations of its shape and the location of its surfaces. The equipment was designed at the OKB SA [not further identified] and manufactured by the Moscow tool plant Kalibr.

A crankshaft is a component with a complicated configuration, is about 1,200 mm long, and has a mass (in the initial production operations) of up to 120 kg, which imposes specific requirements on the design of measuring and test equipment and the organization of inspection.

The following types of measuring and test equipment are used in the automated shop: nonautomatic (manual)

equipment, inspection automatons for interoperation inspection, and an inspection automaton for final inspection.

The nonautomatic inspection equipment is intended for spot inspection of the linear and angular dimensions and deviations in the shape and location of surfaces in all stages of the production process. The resultant measurement information may be used either by an adjuster to correct the setup of a machine tool and replace the tool or by an inspector to assess the quality of the implementation of a production operation. From a design standpoint, nonautomatic inspection equipment is subdivided into stationary instruments and instruments and gauges that are applied.

Stationary instruments are used in those cases where the measurement process calls for basing the crankshaft either along the center holes or along the main bearing journals or else ensuring its angular orientation along the crankpin. The crankshafts are loaded into the stationary instrument by nonautomatic transport equipment.

Figure 1a shows a standard stationary instrument that contains a massive cast bed frame (1) equipped with longitudinal T-shaped grooves. Depending on the instrument's purpose different basing attachments may be mounted on the upper plane: center posts (2) for basing along the axis of the center holes, roller knife-edges (6) for basing along the main bearing journals, or a mechanism for angular basing along the crankpin.

Each center post is equipped with a spindle (12) that rests on a gapless ball bearing and that has the capability of forward motion and turning. The spindle moves with the help of an eccentric lever mechanism controlled by a handle (3). A spring (13) provides an axial force on the spindle. Excess force in the direction of the base stop (5) is created by controlling the forces of the springs of the stationary instrument's center posts. The stability of the force of the axial basing is ensured by the fact that the post spindles (with the crankshaft pressed in them) move on roller bearings, with the magnitude of the force amounting to 20-30 N. By combining the position of the handles (3) on the stationary instrument's center posts the direction of the axial force may be changed to its opposite. A journal (4) on which additional devices (including measuring devices) may be mounted is provided in the front part of the post. A loading mechanism containing intake knife-edge bearings mounted on a shaft (7) that is turned by a handle (8) by means of an eccentric lever mechanism (14) is provided in the instrument to mount the crankshaft on precision base roller knife-edge bearings.

A plate (9) is located on the bed frame. Removable measuring devices are mounted in the plate's grooves. Figure 1b shows a device to monitor the position of the ends of the main bearing journals and crankpins. The device is preadjusted to the zero position in accordance with a meter located outside the instrument, after which it is mounted in series into the plate's guide strips and the position of the ends of the journals relative to the base stop (5) mounted on the same plate subsequently checked. The crankshaft is based along the center holes. The relative positioning of the stop and guide strips is executed with high precision.

The angle between the axes of the crankpins is inspected by the device shown in Figure 1c. The instrument is

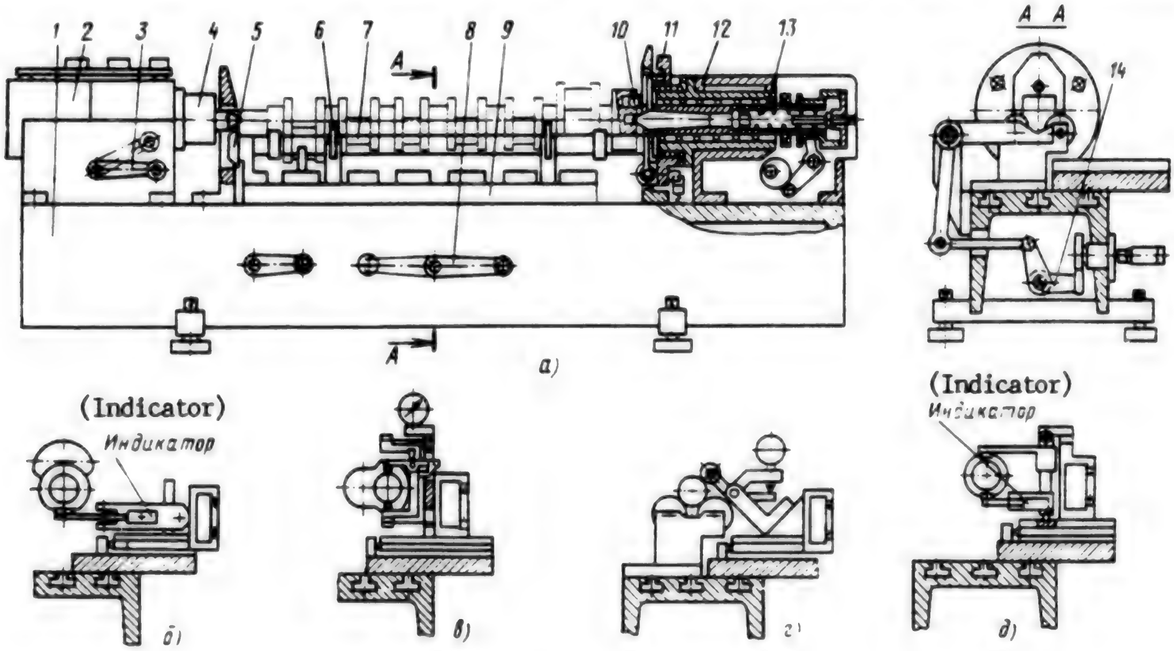


Figure 1

equipped with an index plate (11) mounted on the journal of the center post. An index plate is connected to the crankshaft by a spring-loaded dog (10) with a ball finger. Located on the index plate are pins whose angular arrangement corresponds to that of the crankshaft's crankpins. The measuring device is adjusted to the zero position with respect to one of the crank pins (for example, the first one) of the shaft mounted in the centers. Next, the index plate with the crank shaft turns at an angle equal to the nominal value of the angle between the crank pins and is fixed in this position. The measuring device is secured on the plate opposite of the journal being inspected, and a readout of the deviation from zero is provided.

The devices depicted in Figures 1d and 1e are intended for inspecting the radial and end play both from the axis of the centers and from the axis of the main bearing journals.

Besides the parameters specified above, stationary instruments also inspect the location of the end surfaces of a crankshaft from the vertex of the cone of the center opening, the angular location of the base holes, the position of the keyways relative to the crankpin, the out-of-roundness of the main bearing journals, and the nonparallelism of the crankpins. Stationary instruments are equipped with the required reference gauges, which are located on the bed frame's brackets.

Applied instruments are based directly on the crankshaft's surface. The inspection operations may be performed either in machine tools' intermediate positions or on the transport equipment. Special reference gauges are provided to adjust the instruments. The adjusted instruments are used to inspect the diameters of the turning surfaces, the distances between the journal's ends, the radii of the crank, the deviations from planarity, the length and angles of the cone, etc. Type ICh-10, 1IG, or 2IG mechanical measuring heads are used as readout devices on all stationary and applied instruments.

In crankshaft production gauges are used primarily for comprehensive inspection of such elements as threads, the location of holes, deviations from symmetry, and the profile of the curvilinear surfaces. For element-by-element inspection gauges are used solely when the surface dimensions are small and when inspection by other equipment is impossible.

Automatons for interoperation inspection are used for continuous automatic inspection of a crankshaft in those production operations that determine the quality of products during their subsequent machining. Automatons of this type are used at six points in the production chain.

Figure 2 shows an inspection automaton with the automated line's transport equipment adjacent to it. An overhead manipulator (3) moves the shaft undergoing the inspection from the line's ball transporter (1) to the loading position of the inspection automaton (2). After the inspection has been completed, the manipulator returns a suitable crankshaft to the same transporter but returns a defective crankshaft to the storage unit (6) for defective products.

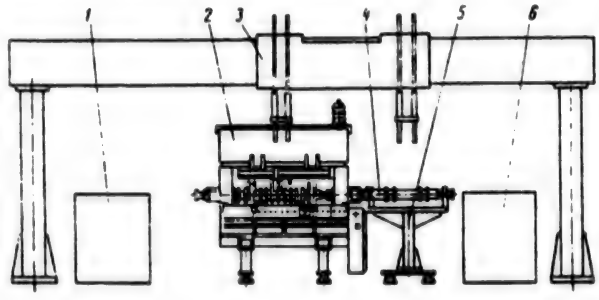


Figure 2

In addition, a manipulator may be used in a nonautomatic mode to place a reference gauge (4), which is located on a special mounting (5), in the automaton's loading position.

All of the automaton's mechanical and electrical elements are located on a single bed frame. The crankshafts in the automaton may be based either on the axis of the center holes or along the main bearing journals. To transfer the shafts from the loading position to the measuring position, a transport carriage is provided in the automaton. The drive for all of the automaton's movable elements is pneumatic.

All the measuring devices are based on a model GI1 inductive lever module (Figure 3 [not reproduced]). Between 3 and 21 crankshaft parameters are monitored on different model automatons, including the location of the ends of the main bearing journals and crank pins, the distance between the ends, the journal diameters, and the radial runout of the main bearing journals.

The measurement information is sent in the form of light signals indicating acceptability or defectiveness with respect to each parameter individually. In the adjustment mode the magnitude of the deviation with respect to each parameter may be assessed on the basis of a scale. Knobs are used to connect to the scale. The number of knobs equals the number of parameters being inspected.

The automaton's electrical control system is based on a programmable controller and makes it possible (when necessary) to make quick changes in the logical circuit of its operation.

The extensive possibilities of controlling the measuring devices and basing elements and of using a programmable controller make it possible to use this automaton as the basis for creating new automatons for different modifications of crankshafts and other analogous components without any serious design changes.

After having passed through all of the machining and heat treatment operations and washing, the crankshaft enters the final inspection automaton.

The link between the automaton and the automated line's transport system is analogous to that for the automatons used in interoperation inspection. The automaton is equipped with a loader that receives a crankshaft from the automated line's overhead manipulator, transfers it to the measuring position, and configures it to base roller knife-edge bearings. A crossarm is located over the measuring zone. Located inside the crossarm are a reference gauge and a mechanism to configure it on the base rollers. The presence of such a mechanism increases the automaton's universality and permits its use in production processes with different types of transport since the overhead manipulator is not expected to perform the function of loading the reference gauge.

The diameters of all main bearing journals and crankpins in two cross sections, the diameters of the flange and conical end, the radial runouts of the main bearing journals, the width and end play of the central main bearing journal, and the crank radius—52 parameters in all—are inspected on the automaton. All parameters are inspected simultaneously as the crankshaft, which is based on two main bearing journals, rotates continuously. A model 221 standard inductive converter manufactured by the plant Kalibr is used as a primary converter in all of the measuring stations.

The automaton's measuring devices have been designed by using a standardized suspension based on elastic elements. The diameter and radial runout of the main bearing journal are inspected by using two suspensions mounted on a bed frame (Figure 4a). Measuring tips (4) that come into contact with the surface being inspected and inductive converters (2) that interact with a fixed stop (3) are mounted on the movable elements (1) of the suspension. The converter of each suspension fixes the fluctuations of the radius of the surface being inspected as the crankshaft rotates or fixes its radial runout. The sum signal of two converters gives the magnitude of the deviation of the diameter of the journal being inspected independent of the position of its axis in the horizontal plane.

The device shown in Figure 4b is intended to inspect the diameter proper. Here a suspension (7) carries a converter (8) that interacts with a stop (6) on a suspension (5). The converter's signal (without additional processing) shows the magnitude of the diameter's deviation.

The device shown in Figure 4c has four standardized suspensions (9), (10), (11), and (12) (a converter is mounted in each of them). The device is intended to monitor the distance between the ends of the main bearing journal and the play of these ends. The difference between the signals from the suspensions (9) and (11) gives the magnitude of the play of the end A, and the

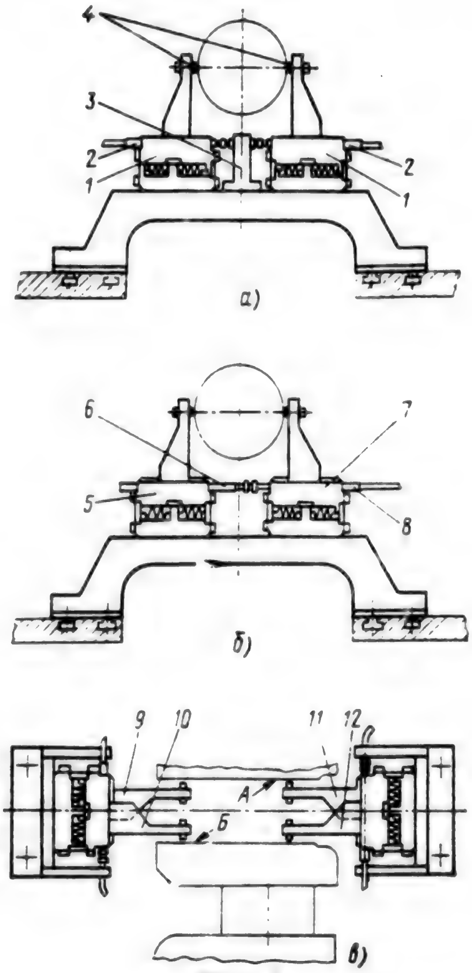


Figure 4

difference between the suspensions (10) and (12) gives the magnitude of the play of the end B. The sum signal from suspensions (9) and (10) fixes the deviation of the size of the distance between these ends.

Measuring devices with a standardized suspension have extensive possibilities for control both along the crankshaft's axis by movement along T-shaped grooves and in a perpendicular direction when the holders of the measuring heads are reconfigured.

The design of an attachment to inspect crankpins is interesting. The diameters of crankpins are measured on it in two cross sections by a device consisting of two standardized suspensions (2) (Figure 5) mounted on a common plate (3) on which a knife-edge bearing (1) is also located. The plate has a conical opening and is pressed by a spring (5) to a cone (4) on a rod (6).

The measuring device's drive is designed in the form of a crankshaft-connecting rod mechanism with a crank radius R equal to the radius of the crank of the crankshaft being inspected. The drive crank (7) is turned by a connecting rod (8) mounted on a shaft (9) located

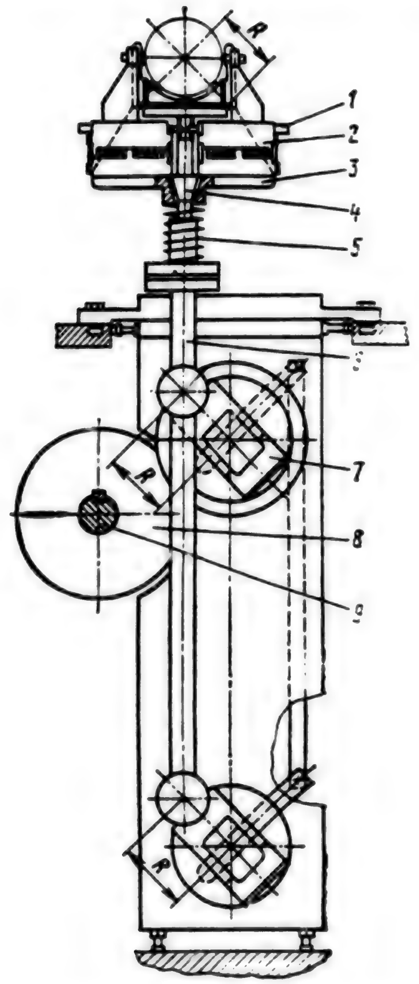


Figure 5

parallel to the crankshaft. Continuous variable control of the radius of the device's crank is possible when readjustment is necessary. The number of such devices in the automaton equals the number of main bearing journals on the crankshaft.

During measurement the conical joint between the plate and rod is opened, and under the action of a spring (5), the measuring device is based along the journal being inspected. During the inspection process all of the measuring devices effect a parallel motion relative to the axis of the crankshaft and set it into motion. The automaton's mechanisms are moved by a pneumatic drive.

The automaton's control circuit is based on a programmable controller. Measurement information is sent to a display panel in the form of light signals about suitability and defectiveness with respect to each parameter individually. In addition, a number of scales encompassing a group of parameters and switched on by knobs are provided on the display panel. The threshold deviations of the dimensions with respect to each parameter (the greatest and least value individually) and the magnitudes of the spread of the amplitude measurements may be assessed in accordance with the scales. Measurement information is stored in the automaton's memory for 2 minutes after the measurements have been completed.

The automaton may operate in automatic and semiautomatic modes, where a decision regarding a product's suitability is made by the operator-inspector after he assesses the instrument results on the basis of the information display panel.

Thanks to the measuring and test equipment's wide control range and the presence of a programmable control based on the given automaton it is possible to develop units to test different type sizes of crank shafts.

The proposed integrated development of testing methods and equipment in automated production makes it possible to standardize circuit and design decisions and create a park of spare assemblies and components, which is required for the normal operation of measuring and test equipment.

UDC 531.7.08

System of Standardized Components for Universal-Module Measuring Attachments

907F0080R Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 14-16

[Article by I. N. Khaskin, candidate of technical sciences]

[Text] A system of standardized components for universal-module measuring attachments to unitize the equipment to monitor the linear dimensions of machine building components has been developed and is being introduced at the Minstankoprom [Ministry of the Machine Tool and Tool Industry] OKB SA [not further identified]. Created in the first stage were elements from which it is possible to configure one- and multidimensional instruments for manual inspection of shaft-type components (Figure 1) [photograph not reproduced]. Upon further development, the system will make it possible to encompass other types of products subject to inspection and different types of measuring and test equipment. The universal-module attachment system should help overcome those problems that currently arise during the order, manufacture, and introduction of equipment to monitor linear dimensions.

It is currently difficult for users of measuring and testing technology to place an order for shipment of the instruments, inspection and blocking devices, and automation equipment it needs. The procedure for ordering the simplest instruments is as complicated as that for ordering complicated automatons. The times required to fill orders reach 1.5-2 years or more at a high cost.

Enterprises creating measuring and test equipment by their own efforts need to produce increasingly specific measuring device components independently since centralized manufacture of them has not been set up. As a

result all developments have an original design, which further complicates the operation and repair of measuring and test equipment.

The OKB SA is currently solving a set of organizational and technical problems related to practical introduction of a system of standardized components for the universal-module attachment system and is taking orders to ship manual inspection instruments made up of these components. Individual components and sets of components from the universal-module attachment system will be sold to those enterprises wishing to configure instruments by their own efforts, and specialists from the OKB SA will supply the necessary methodological and technical assistance.

Acquiring sets of universal-module attachments may also be useful to conduct practical studies at educational institutions specializing in training designers and metrologists for machine building enterprises.

It is proposed that the procedure for ordering new instruments be changed. When contacting the OKB SA, the party placing the order must send two or three full-scale specimens of the product to be inspected after that production operation for which the inspection is to be performed. When it decides to fill the order, the OKB SA reproduces a mockup of the specialized instrument from the finished elements of the universal-module attachment system present. When necessary, individual original components are manufactured according to drawings. The mockup of the instrument is presented to the customer for approval, after which a shipment agreement including time frames and costs is formulated. A number of technical requirements that could not be foreseen when the order was compiled may be refined in this stage. A full-scale model of the instrument but not the sketch (as was done previously) is checked with the customer.

Such a procedure for ordering new instruments has become possible thanks to the extensive universality of standardized components.

The component set for the model USON1 (Figure 2) [photograph not reproduced] universal-module attachment system that has been prepared for introduction into practice contains five groups of components: bases, basing devices, transmitting heads, structural components, and accessories.

Five type sizes of cast iron plates have been provided to serve as bases. The plates have a ribbed structure and are rather stiff. The plates are furnished with T-shaped grooves so that the components of the instrument can be secured in any position required. The plate has shoulders 40 mm long on both ends for convenience in transporting instruments. Four M10 holes for standard supports are provided below. By configuring different-height supports it is possible to provide the slope of the axis of the inspected product that is required in some cases.

Basing on centers and knife-edge bearings has been provided for shaft-type products with a mass up to 8 kg. Standard centers with a Morze No. 2 cone at a height of 100 mm over the upper plane of the plate are mounted in the sockets of the center heads. The distance between the centers may be established in the range from 325 to 675 mm depending on the size of the plate.

Basing knife-edge bearings with angles of 90 and 120 degrees are in the set. Each knife-edge bearing consists of a body and controllable hard-alloy supports. The diameter of the basing surfaces may fluctuate in the range from 5 to 60 mm, while the axes are permanently located at a height of 100 mm. The greatest distance between supports depends on the length of the plate, and the least distance is not limited for all practical purposes. A post with a yoke for securing a readout device with a connecting dimension of 8 mm may be mounted on any knife-blade bearing. The readout device on the knife-edge bearing with a 90-degree angle determines the outer diameter of the product being inspected, whereas the knife-edge bearing with the 120-degree angle determines the out-of-roundness with a gain factor equal to 2.

For basing the product being inspected in an axial direction there is a bracket with a vertical slot in which different stops and a readout device may be mounted.

The set includes a group of transmitting heads that may be used in devices for manual inspection of linear dimensions independent of the type of product being inspected. The heads are equipped with various measuring tips and provide for configuring any readout device with a connecting dimension of 8 mm.

Elements included as components of the set serve to mount the measuring and basing devices on the plate, provide the required relative location of the instrument's components, and perform possible auxiliary functions. The structural components are rendered universal by using T-shaped slots with sunk blocks, cylindrical rods with split yokes, connections in the form of a dovetail, and other types of connections.

In those cases requiring that the measuring tips be withdrawn to mount the product being inspected on the instrument, the transmitting heads may be furnished with an eccentric or pneumatic arresting mechanism. An eccentric arrester can control just one head, and a pneumatic arrester is used in those cases requiring simultaneous control of several measuring tips or in cases where they are located in an area that is not convenient to service.

The product being inspected may be turned continuously by hand (from a flywheel) while it is based on knife-edge bearings or in centers. The drive consists of a steadyrest ad flywheel supports. In the case of a horizontal implementation, the transmission ratio from the flywheel to the drive shaft amounts to 1:1. In a tilted execution the transmission ratio may be controlled between 1:1 and 1:0.4 by reconfiguring the roller relative to the cone. The rotation is transmitted from the flywheel to the

steadyrest by a roller with square ends. The drive rollers, which are paired with pulleys, are pulled by a spring and form a floating system that is closed on the product being inspected. A round belt is used to transmit the rotation. Drive roller positions to rotate products 5 to 60 mm in diameter are provided. The drive rollers' axes may be set at an angle relative to the product's generatrix, which clamps the product to the fixed axial base when necessary.

To load and unload the product being inspected there is a lever system to control and fix the drive rollers in the extreme positions.

The high-speed clamp has two fixed positions: working and loading. In the working position the product is squeezed with a force of 15 N thanks to the presence of a spring-loaded sleeve.

The accessories included in the set contain hand and measuring tools and attachments for unitizing instruments from standardized components. The necessary spare parts and materials are provided.

Figures 3, 4, and 5 [photographs not reproduced] are examples of standard configurations made from the set's components. Figure 6 [photograph not reproduced] shows an instrument on which only 20 percent of the components are original. Its main components are made of the set's components.

Despite all of the advantages of a system of standardized components for a universal-module attachment system, there are also a number of objective and subjective obstacles to its wide-scale development. One of the main ones is the redundancy of its structures. Standardized components possess extensive universality that is not, in practice, realized in each individual instrument. But if redundancy does not make instruments more expensive, this obstacle may be overcome. The cost of standardized components will decrease as the size of the series in which they are produced increases. This in turn will depend directly on the extent of their use.

The established practice of planning the labor intensity of design work and providing material incentives for developers gears them toward creating complicated products with a design innovation and multitude of original components. An analogous situation is taking place in the manufacture of new products of measuring and test technology. In this atmosphere introducing a system of standardized components encounters natural resistance on the part of developers and manufacturers of new technology.

Solving this psychosocial problem requires restructuring the entire system of planning, price formation, and provision of material incentives for all those participating in creating new measuring and test technology. It should be based not on expenditures of producers but rather on modification of the technical indicators of the products manufactured, their precision, productivity, reliability, and ergonomic and other consumer qualities. The creative potential of designers and others participating in creating measuring and test technology should be targeted toward this.

The OKB SA of the Ministry of the Machine Tool and Tool Industry has decided to assume the function of a firm that not only does planning work but that also performs an entire set of duties related to manufacturing and supplying instruments for manual inspection of machine building products.

UDC 531.717.12;531.729.4

Small Modules To Inspect Stationary Base Components

907F0080S Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 16-18

[Article by V. L. Gabinov, candidate of technical sciences]

[Text] When various stationary base members (engine cylinder blocks, block heads, gear box cases, etc.) are inspected, a large number of holes (10 or more) are generally measured by introducing measuring gauges into these holes.

Significant difficulties have arising in designing measuring gauges. These are related to the need to locate a large number of converters (transducers) in them along with the mechanical portion of the measuring systems (levers, flat-spring suspensions, etc.), arresting devices, and electrical and pneumatic communications.

This is especially apparent when inspecting five to seven sequentially arranged coaxial holes under crankshafts and camshafts in cylinder blocks where the diameter of the holes is between 50 and 70 mm and where the block is between 500 and 800 mm long. For this reason, in the past few years different types of small measuring modules have begun to be used increasingly widely, both in our country and abroad. They are used when inspecting holes together with commercial series-produced inductive transducers.

The advantage of measuring modules is that they are capable of integrated performance of the principal functions of measuring systems, including the following: converting the movements of the measuring tips into an analog electric signal, expanding the measurement range of the converter by using precision transmission mechanisms, configuring the measuring tips in the plane of the diameter of the hole being inspected (centering the tips), arresting the measuring tips after the measurement has been completed, and obtaining a reference stable electric signal (that is used to automatically check the operability of the entire electronic measuring channel) from the converter after the measuring tips have been arrested. All of the measuring module's mechanisms are located in one case that has elements to display and secure them in the measuring gauge. Using similar measuring gauges

makes it significantly easier to switch to modular methods of developing them.

In the past few years the OKB SA has created a number of measuring module designs, including some to inspect holes in stationary base members (for example, the model 400, model 470, and model MIM measuring modules [photographs not reproduced]). These are characteristic representatives of such devices.

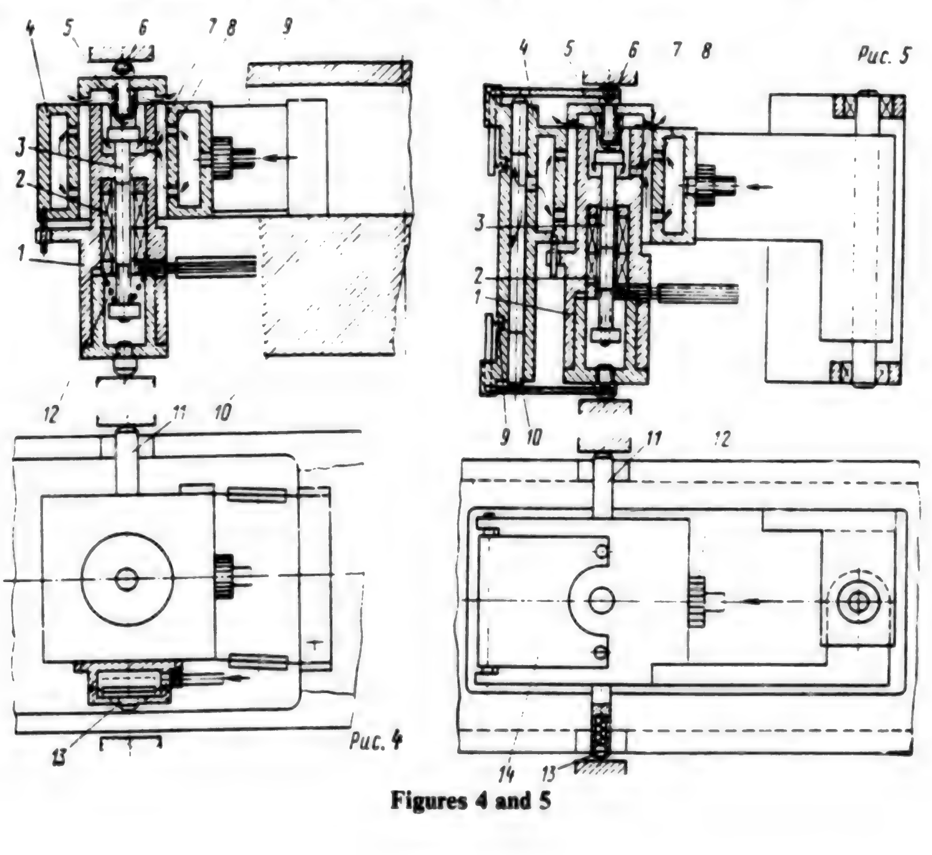
These models have rather small overall dimensions and a shape that is convenient to build into different types of measuring gauges or into the cylinder boring bars of boring machines to inspect hard-to-reach holes in stationary base members with a complicated configuration.

The distinction of the design of all of the models of measuring module examined is their use of an inductive measuring system of series-produced converters (model 221 from the plant Kalibr or model 76503 from the Leningrad Tool Plant imeni S. P. Voskov) in conjunction with the feeding of compressed air into the measuring module. The latter is done for the following purposes: to create aerostatic-type guides for the moving measuring rods, to constantly blow the inner cavities of the measuring module and create a positive pressure in them, and to pneumatically control the position of the measuring tips with respect to two coordinates. Using compressed air makes it possible to provide a rather high measurement precision with a relative simplicity of configuring the measuring modules as well as reliable protection of their mechanisms from contamination under shop conditions. The model 400, 470, and MIM measuring modules may therefore be termed aeroinductive.

The model 400 and 470 measuring modules are intended solely for measuring the diameters of holes, and their measurement circuits are similar in many ways. They include a two-contact inductive converter that floats in an axial direction within the bounds of 1 mm for self-alignment on the hole being inspected and mechanisms to center the measuring tips in the hole being inspected and to arrest them after the measurement has been completed.

The converter consists of a bushing (1) (Figures 4 and 5) that moves on the aerostatic supports (8) of the case (4) and a rod (5) that moves in the bushing's opening. Hard-alloy measuring tips (6) are located on opposite faces of the bushing and rod. Coils (2) are mounted inside the bushing, and a core (3) is mounted on the rod. The inductive measuring system therefore fixes only the relative movements of the bushing and rod. Compressed air is fed through special holes (7) in the bushing. It exits the aerostatic supports, is fed into the gap between the bushing and rod, and provides a measuring force on the tips and protects the inner cavity of the bushing against contamination from without.

The centering mechanism of the measuring tips is made is several versions:



Figures 4 and 5

—in the form of a rigid stop (11) located on the plane of the diameter perpendicular to the common axis of the measuring tips at a distance from this axis equal to the radius of the hole being inspected. The rigid stop is pressed to the surface of the hole being inspected by a pneumatically controlled telescopic stop (13) (in the model 400 measuring module in Figure 4) or a spring-loaded ball (13) (in the model 470 measuring module in Figure 5);

—in the form of pneumatically controlled centering pieces (15) (Figure 5) (in the design of the model 470 measuring module) that operate from rods (10) to which compressed air is fed from a common inlet (12) through a hole in the case. The centering pieces are also used to arrest the measuring tips with the help of opposing springs (9) after the compressed air has been switched off. The measuring tips of the model 400 measuring module are arrested by a return spring (12) (see Figure 4) after the compressed air has been switched off.

Compressed air fed from a PPV-type unit with a stabilized pressure of 0.3 MPa is used to control the operation of the model 400 and 470 measuring modules.

The differences in the configuration of the model 400 and 470 measuring modules is determined by the design features of the measuring gauges into which they are built. As is evident from Figure 4, the model 400 measuring module is convenient to build into measuring gauges in the form of mandrels separated along the axis. In this case the fully assembled measuring modules are secured on the open plane of the joint of the base portion of the mandrel (10). After all of the measuring modules included in the given measuring gauge have been configured and the air hoses and electric lines have been laid, the cover (9), which turns the mandrel into a full cylinder, is secured to the base portion. This type of design makes assembling the measuring gauges much simpler, and it is especially convenient when configuring several measuring modules in a measuring gauge to inspect coaxial holes that lie close to one another.

The minimal distance between the cross sections being measured when the model 400 measuring module is used amounts to 50 mm, with the diameter of the holes being inspected ranging from 50 to 100 mm. A similar measuring gauge and measuring module design has been used successfully for automatons to inspect cylinder blocks at the Melitopol Engine Building Plant.

As is evident from Figure 5, the model 470 measuring module is convenient to build into measuring gauges made in the form of tubes with longitudinal through slots. These types of measuring gauges are mainly used when inspecting holes in large-sized stationary base members, for example, the engine cases of the Don-1500 combine and the cylinder blocks manufactured by the Yaroslavl Engine Building Plant and the Moscow Automotive Plant imeni I. A. Likhachev.

The minimal distance between cross sections being measured when the model 470 measuring module is used amounts to 150 mm, with the diameter of the holes being inspected ranging from 50 to 150 mm. The model MIM side-action measuring module is intended to inspect both the outer and inner dimensions (diameters, thicknesses, etc.) and the relative locations of axes and surfaces, including play. The rectangular configuration and small overall dimensions (70 x 13.5 x 12 mm) of the MIM have been dictated by the need to build it into measuring gauges that are introduced into holes 30 mm or less in diameter to a depth of up to 600 mm. In this case, using another other type of measuring module developed at the OKB SA was virtually impossible.

The coils (4) of an inductive converter are secured in the case (9) (Figure 6) of the MIM. The rod (11) and core (10) of the converter move in the hole of the case along the axis of the coils and contact (by the small end) the lever (2) carrying the measuring tip (1). The lever is raised to the case on a half-cross of flat springs (3) and is pressed continuously to the end of the rod by a spring (12). The latter is pressed (by its large end) to a pneumatically controlled elastic membrane (5) that transmits to the lever the measuring force that is created by the pressure of the compressed air fed into the chamber (6). The rod is prevented from turning by a floating pin (8) that moves easily in the guide bushing's groove (7). After the air pressure in the chamber is removed, the lever (under the action of the spring (12)) returns to its initial position and arrests the measuring tip at 1 mm.

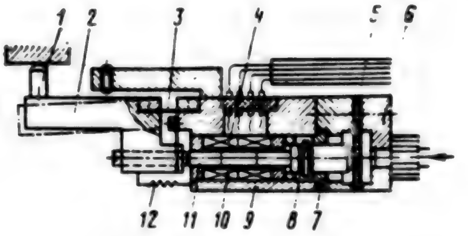


Figure 6

The MIM is mounted in the longitudinal grooves of the measuring gauge or the cylindrical boring bars of machine tools (depending on the type of key) and is secured on the side walls of the groove by a dovetail-type guide. The minimum distance between the cross sections measured when several types of MIM modules are mounted in one line amounts to 80 mm, with the minimum diameter of the holes being inspected being 30 mm (in the case where the diameter is monitored by two MIM modules along a differential circuit).

In the case where one of the MIM modules is replaced by a rigid measuring tip, the diameter that can be inspected is reduced to 15-20 mm depending on the design of the measuring gauge. The model MIM measuring module is being used increasingly widely to equip inspection automatons developed by the OKB SA for many plants in the automotive industry.

To determine the metrologic and performance characteristics of model 400, 470, and MIM measuring modules, test batches of them were manufactured and tested at the OKB SA. The tests were conducted on special stands under static and dynamic operating modes. The measuring tips were arrested automatically by a special pneumatic drive with a cycle of 4 to 5 seconds during accelerated reliability tests. The results of the metrologic tests were determined by using a digital voltmeter.

The following principal metrologic characteristics were determined: nonlinearity of the characteristics (in the range of plus or minus 100 µm for all models of measuring modules and also in the range of plus or minus 300 µm for the model MIM measuring module), the spread of the readings (based on standard end and special reference gauges), the variation of the readings, the shift of the adjustment over time (at an environmental temperature of 20 plus or minus 1°C), the measuring force, and the shortest activation cycle. Additional characteristics, including the following, were also determined: the shift of the adjustment upon a change in the environmental temperature in the range from +15 to +40°C, the spread of the readings when the roughness of standard and special specimens was measured (to assess the effect of different roughnesses on the stability of the measurements), and dynamic characteristics. After this, protracted reliability tests were conducted in an accelerated mode. The resultant values of the principal metrologic characteristics are presented in Table 1.

Table 1

	Type of Measuring Module			
Metrologic Characteristic	400	470	MIM	MIM
Measurement range, µm	+/- 100	+/- 100	+/- 100	+/- 300
Sensitivity mv, µm	100	100	100	35
Nonlinearity of the characteristic H, µm, not more than	0.8	0.4	0.6	1.2
Spread of readings R, µm, not more than	0.2	0.3	0.3	0.3
Variation of readings B, µm, not more than	0.2	0.5	0.7	0.7
Shift of adjustment (zero) C, µm (in 8 hours of operation with an air temperature of 20 +/- 1°C), not more than	1.5	0.7	1.5	1.5
Shortest activation cycle, s	0.5	1	0.5	0.5
Measuring force, g (with a controlling air pressure of 0.2 MPa)	120 +/- 10	150 +/- 20	120 +/- 10	120 +/- 10

The following results were obtained during the accelerated reliability tests of the measuring modules: MIM, more than 30,000 activations with a cycle of 0.5 seconds; model 470, more than 500,000 activations with a cycle of 1 second; and model 400, 1.5 million activations with a cycle of 0.5 seconds. No failures in the functioning of the modules were detected.

The metrologic characteristics presented in Table 1 may be used to determine the limiting errors of the measuring modules for the different versions of using them (the variation of the readings was not considered in the given case since in all of the measuring modules examined the measuring tips [after the arresting] approach the surface being inspected from one side):

—in the absence of automatic zero drift adjustment in the inspection device

$$\Delta \lim = (H + C) + (1/2)R;$$

—in the presence of automatic zero drift adjustment in the inspection device

$$\Delta \lim = H + (1/2)R.$$

The resultant data showed that introducing automatic zero drift adjustment into the measuring device increased the measuring module's precision between two and two and a half times, which is especially important during operational inspection to issue well-founded instructions to align machine tools.

The measuring modules examined may thus be used in the absence of a zero drift adjustment in the inspection device to monitor dimensions with smallest tolerances of 20 µm; when such an adjustment is present, they may be used to monitor dimensions with smallest tolerances of 10 µm.

The minimum activation cycle for all of the measuring modules examined can, for practical purposes, amount to 1 second (for both versions). When selecting the versions of measuring modules to use, however, it should be borne in mind that under real shop conditions there are a significant number of additional sources of drift in the adjustment (zero) of the measuring module that are related to fluctuations in the temperature of the components being inspected and the surrounding air, the wear of the measuring tips, etc. In many cases the second version of using a measuring module (i.e., automatic zero drift adjustment) is more feasible to ensure the specified measurement precision, particularly during operational inspection in automated lines.

The results of tests on the types of measuring modules examined show that there are reserves for further increasing their precision. This requires improving the design and technology for manufacturing measuring

modules to bring the values of the spread of their readings to a stable value on the order of 1 μm and to use a computer to automatically compensate for the nonlinearity of the measuring modules' characteristics.

UDC 621.824.33.002.56

Layout and Inspection Automaton

907F0080T Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 18-19

[Article by Ye. A. Acharkan]

[Text] A new-generation automaton to inspect the camshafts of diesel engines has been developed at the OKB SA. It is intended for use as a component of an automated line to produce camshafts and is mounted at the line's outlet as a piece of acceptance inspection equipment. The automaton is connected with the automated line's transporter by a gantry loader in the form of an industrial robot with two built-in magazines that have separate drives. The magazines serve to receive the camshafts separated on the basis of the inspection results into acceptable and defective camshafts and for the camshafts' intermediate storage on special pallets. The latter are stacked into multitier storage units, which permits rational organization of the process of sending camshafts to the warehouse by a shop fork loader. The industrial robot has its own programmable controller to control all of its movements connected with performing its loading and unloading functions. Its program also provides a mode to return camshafts from the magazine to the automaton for repeat inspection and a mode to feed a reference gauge into the automaton for automatic alignment of the measuring system.

The layout and inspection automaton is designed in the form of a unit where all of the nodes and mechanisms are concentrated and a freestanding post with the electrical equipment. The movable nodes are self-contained and are equipped with pneumatic drives. For the sake of the operator's convenience and occupational safety, the loading zone is shifted somewhat relative to the measuring station, which distinguishes the given automat from those constructed previously and opens optimum access to all of the servicing sites.

The acceptance inspection of multiple-bearing and insufficiently stiff camshafts entails continuous checking of exact tolerances for a large number (on the order of 40) of dimensional parameters. These include the following: the diameters of all the bearing journals in two cross sections with respect to length, the ovality of the bearings with respect to each cross section, the conicity of all of the bearing journals, the end play of the extreme bearing journals, and the radial play of the cylindrical portion of the cams. Most of the parameters are inspected in accordance with a two-point measurement scheme using inductive transducers whose contact tips lie in pairs along the plane of the camshaft's diameter. The transducers' signals are processed continuously during the time of one rotation of the camshaft with a readout of the parameters in accordance with the specified algorithms. Since the camshafts in the automaton are based in centers and the checking of the plays is specified from the common axis of the extreme journal bearings, the necessary compensating corrections are included in the play algorithm.

The automat includes a programmable controller with analog-digital input that, besides providing a mutual link between the operations of the self-contained nodes, also calculates the values of the parameters, stores the measurement results in its RAM, and makes it possible to print out the measurement results for each parameter onto the device's digital reading display screen. Using a programmable controller in the automation increases its operating reliability and, at the same time, expands its production capabilities. These capabilities include the following: editing the control program directly at the workstation, automatic alignment by making a zero adjustment based on a reference gauge, exchanging information with a higher-level computer, and outputting information to the automated line (for automatic correction of control programs based on the measurement results).

The inspection automaton developed may thus be considered . principal component of an inspection module that is suitable for operation in a computer-integrated manufacturing system in a mode based on a technology that uses few people.

UDC 531.717.5:621.9.08;621.993.08

Readjustable Applied Instrument To Inspect Threads of Lead Screws

907F0080U Moscow MASHINOSTROITEL in Russian No 10, Oct 89 p 19

[Article by A. S. Glikin, candidate of technical sciences]

[Text] Modern machine building imposes high requirements regarding the precision of manufacturing screw pairs. The kinematic precision of machine tools, particularly NC machine tools where rocking screw pairs are used, are largely dependent on them.

The screws' thread is ground in several passes, and in each pass the three-wire method is used to measure the inner diameter of the thread in no fewer than three sections along the screw's length, which requires a significant amount of time and high qualifications on the part of the inspector. The low productivity of the measurements coupled with a low precision reduces the productivity of the thread grinding.

The OKB SA of the Ministry of the Machine Tool and Tool Industry has created a readjustable applied instrument (author's certificate no. 1147918) that monitors the inner thread diameter of rocking screws with right and left directions. It is intended to monitor a thread during the process of manufacturing screws without taking them

from machine tool's production bases and for final inspections at points of technical control stations.

The instrument is manufactured in two versions: a large model, the 5152M (with type sizes 50 x 5, 50 x 8, 50 x 10, 63 x 10, 63 x 20, 70 x 10, 80 x 10, 80 x 20, 100 x 20), and a small model, the 5152M-01 (with type sizes 25 x 5, 32 x 5, 32 x 10, 40 x 5, 40 x 6, and 40 x 10).

The readout device has a scale factor of 0.001 mm, it has a measurement range of 1 mm, and the mass of the instrument is not more that 0.9 kg with overall dimensions of 260 x 45 x 210 mm. The instrument is adjusted on the basis of a certified component of the existing production process.

Mounted to the instrument's case (6) are a lever (5), readout head (7), and a flat bearing (4) for basing. The lever is mounted in the case on roller bearings. A fork (3) with a cylindrical measuring tip (2) located in the centers (1) is mounted on one of its ends. The heel (9) on the second end of the lever acts on the readout device. A spring (8) contains a measuring force. Another fork with an analogous design is mounted on a bracket (11) that is in turn connected with the instrument's case.

To measure an outer thread with a different diameter and with different helix angles, when the flat bearing for basing is readjusted, it may be moved. Each fork with its measuring tips may also move along the mounting axis and turn relative to this axis. In addition, the bracket may be moved relative to the case along the mounting axis and turned relative to this axis.

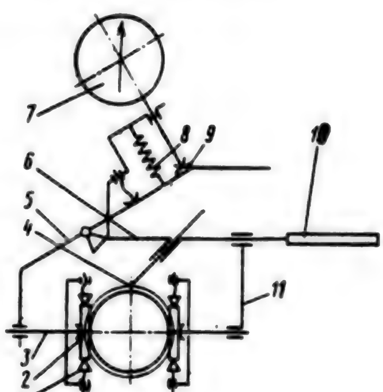


Figure 1

When necessary, terminals with cylindrical tips are used instead of a fork (3). These terminals make contact with the spherical portion of the thread being measured or with the end of its cylinrdrical part.

The instrument is taken by the handle (10), the lever is moved, the measuring tips are inserted into the flat space of the thread being measured, and the instrument is lowered to the flat bearing for basing. The lever and handle are then released. The lever may also be released until the flat bearing touches the surface of the component being measured, and the hand is then released.

The measurement results are fixed on the basis of the readout device's readings. Because the instrument aligns itself on the component being measured, it is based reliably, and no additional manual support of the instrument is required during the measuring.

Several batches of model 5152M instruments have been manufactured at the OKB SA and at the Kirov Red Toolmaker [Krasnyy instrumentalshchik] Tool Plant. They are being used extensively in grinding rocking screws at the Odessa Precision Machine Tools Plant. The instruments have been introduced at dozens of other machine building plants.

At the Ryazan Machine Tool Plant's production association introduction of the instruments in screw-grinding operations made it possible to double the precision of measurements and to increase measurement productivity fivefold.

When the respective replaceable components are present, it is possible to measure the average diameter of slide friction screws (with a trapezoidal profile), the diameter of cylindrical surfaces and grooves, the base difference of outer cones (author's certificate no. 1384919), the distance between the outer surfaces of components in cases where the surfaces being measured are located at different heights relative to the base surface (for example, the axes of centers), and a number of other parameters. Orders for manufacture of the model 5152M are being accepted by the Odessa Automatic Inspection Instrument Plant.

UDC 531.717.5;621.924-503.57.08

Active Monitoring Instruments for Adaptive Control of Grinders

907F0080V Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 20-21

[Article by V. Ya. Ryumkin, candidate of technical sciences]

[Text] The OKB SA of the Ministry of the Machine Tool and Tool Industry has developed a number of active monitoring instruments for adaptive control of grinders performing infeed circular, eccentric, and internal grinding. The instruments use information about the running size of the workpiece, the cutting power, the rate at which the allowance is removed, and the time constant of the cutting process. One example is the model KU75 active monitoring instrument for adaptive control of circular grinding automatons.

It consists of two inductive single-contact heads (Figure 1 [not reproduced]) with an electromagnetic drive to arrest the measuring tips and an electronic control unit (Figure 2 [not reproduced]). A device to control the arresting of the measuring tip is built into the inductive head.

Figures 3 and 4 show a block diagram of the instrument and the cycle of machining in accordance with an algorithm that is implemented when using the instrument. The cycle consists of stages of rough (1 through 4) and finishing (4 through 7) grinding. The rough grinding stage includes infeeding in a preliminary rough feed (steps 1 and 2) and grinding with stabilization of the cutting power (steps 3 and 4). The finishing grinding stage consists of preliminary sparking-out (steps 4 and 5), grinding with cutting power stabilization (steps 5 and 6), and final sparking-out (steps 6 and 7).

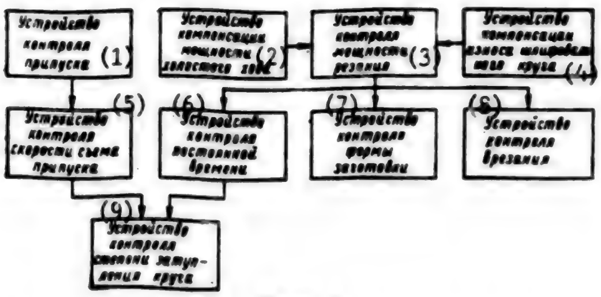


Figure 3

Key: 1. Device to monitor allowance 2. Device to compensate for shut-off power 3. Device to monitor cutting power 4. Device to compensate for wear to grinding wheel 5. Device to monitor rate at which allowance is removed 6. Device to monitor time constant 7. Device to monitor shape of blank 8. Device to monitor infeed 9. Device to monitor degree of dulling of wheel

The control instructions 1P through 6P (see Figure 4) are formulated on the basis of the results of monitoring the cutting power, whereas the instructions 2O through 4O are based on the results from monitoring the allowance remaining for the machining. The instruction Φ is formulated on the basis of monitoring the shape of the machined surface in its cross section, the instruction T is based on monitoring the cutting process' time constant, and the instruction V is based on monitoring the rate at which the allowance is removed. In addition, when blanks arrive for machining with an allowance that exceeds the admissible value, the instruction 1O to reject this blank is formulated.

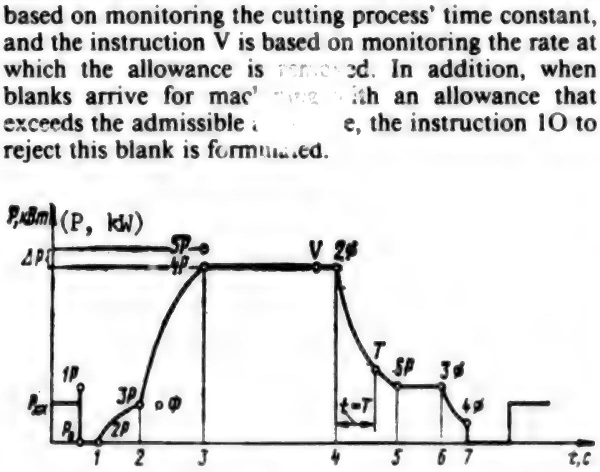


Figure 4

A peak detector with a bit loop based on an exponent whose time constant is set lower than that of the cutting process is provided to eliminate the effect of the error in the shape of a workpiece in its cross section on the precision of formulating the control instructions 1P through 6P and T.

The shut-off power P_{xx} (see Figure 4) is stored at the beginning of the machining cycle. After accelerated feed of the grinding wheel to the workpiece, the power P_{xx} is stored once again and compensated for. In the case of complete compensation, the instruction P_0, which includes forced feed, is activated. Comparing the magnitude of the power P_{xx} makes it possible to obtain information about the infeed of the grinding wheel into the blank with an accelerated feed in the case where the machine tool is incorrectly aligned (author's certificate no. 921823 and 1071414).

Two criteria for terminating the grinding in the preliminary feed stage and formulating the control instructions 3P and Φ to switch on the first preliminary feed are provided in the algorithm under examination. In the case where the first criterion is used, the grinding is terminated in the preliminary feed stage when the width of the grinding is increased (the initial error in the shape of the workpiece in the longitudinal section is reduced) to a specified value that corresponds to the level at which the instruction 3P is activated. In the case where the second criterion is used, the reduction of the initial error in the shape of the workpiece in its cross section to a specified value (the instruction Φ) determined on the basis of the amplitude of the fluctuations in cutting power is an additional condition for terminating the preliminary grinding. If the initial errors in the shape of the blank are not a limiting factor on the threshold load on the grinding wheel, stages 1 and 2 may be eliminated from the machining cycle. In this case the first rough feed is switched on at the initial moment of the infeed of the grinding wheel into the blank in accordance with the instruction 2P.

When the power is increased to the level of the activation of the instruction 4P, the second rough feed (which is smaller in magnitude than the first feed) is switched on. Further grinding is implemented in a power stabilization mode (sections 3 and 4 in Figure 4) during subsequent switching of the first and second rough feeds. If the magnitude of the re-regulation ΔP of the power during grinding exceeds a specified value, the instruction 5P for an emergency shutdown of the machine tool is activated.

When the rough allowance is removed, the instruction 2O to switch off the rough feeds is formulated, and further grinding is done in a sparking-out mode (sections 4 and 5). The value of the time constant T of the cutting process is measured during the sparking-out process. It is defined as the time elapsing between activation of the instruction 2O and the moment when $P(t) = 0.37\ P_{beg}$, where P_{beg} is the value of the power (in memory) when the instruction 2O is activated.

If the measured value of T turns out to be greater than the specified value, the instruction T to correct the grinding wheel is formulated (author's certificate no. 634922).

When the power in the sparking-out process is reduced to the level where the instruction 6P is activated, the power is stabilized (sections 5 and 6) by sequential on- and offswitching of the rough feed in accordance with the instruction 6P. When the allowance is reduced to the value corresponding to the level at which the instruction 3O is activated, the rough feed is switched off, and the final sparking-out is implemented (sections 6 and 7). The machining is terminated upon the instruction 4O.

The criterion for determining the degree of dulling of the grinding wheel based on monitoring the time constant T assumes the constancy (adjusted to the cutting zone) of the rigidity I of the manufacturing system, at least in the period between the fine adjustments of the instruction T since the time constant T is an integral estimate of the cutting power of the wheel and the rigidity I:

$$T = 1 K_p I,$$

where K_p is the coefficient of the grinding wheel's cutting power. This dependence is valuable for most infeed grinding processes, which may be viewed as inertial links. In that case, the change in power during the sparking-out stage occurs in accordance with an exponential dependence $P(t) = P_{beg}e^{-1/T}$. After substituting the value $t = T$, we obtain the very first dependence.

For the case where the rigidity I of the manufacturing system is a variable quantity when a batch of workpieces is machined (for example, when grinding the belts of engine cylinder sleeves on ME252SO with basing of the workpieces along the hole on an aerostatic mandrel), the instrument has the capability of diagnosing the status of the grinding wheel's cutting properties based on monitoring the rate v at which the allowance is removed in a rough grinding section (sections 3 and 4) with stabilization of the cutting power (author's certificate no. 1110616).

It is known that the cutting power P and the rate v at which the allowance is removed are connected by the following dependence:

$$P = (v/K_p\varphi)v_p,$$

where v_p is the cutting speed and $\varphi = F_y/F_z$ is the cutting force ratio coefficient (the radial force F_y and the tangential force F_z).

It follows from this equation that when the power is stabilized and when all other conditions are equal the speed v is proportional to the coefficient K_p.

It has been experimentally established that, for most grinding wheel-machined material-cutting fluid combinations, the changes in K_p and v have little effect on the cutting force ratio coefficient. To compensate for the effect of the change in cutting speed as the grinding wheel wears out, the instrument has a device to count the number of corrections and to automatically correct the cutting power stabilization levels.

Consequently, by measuring the rate at which the allowance is removed, it is possible to obtain information regarding the degree of the dulling of the grinding wheel and to use it to determine the moment of the correction. The speed is determined in a grinding section with power stabilization (sections 3 and 4) by measuring the time required to remove a specified allowance ΔO. This allowance is monitored with an allowance for the running error in the shape of the surface being machined in the cross section being monitored. If, when the next workpiece is ground, the rate at which the allowance is removed decreases to the level at which the instruction V is activated, the grinding wheel is corrected before the beginning of the next cycle.

For convenience in adjusting the loops monitoring the time constant of the cutting process and the allowance removal rate, there is the capability of connecting the leads of these loops to the instrument's indicating devices.

The combination in the instrument of dimensional monitoring during the machining process and monitoring of the force parameter provides the greatest efficiency of controlling the cutting process over the course of the entire machining cycle thanks to the following:

—reduction of the "air grinding" time and control of the initial stage of the grinding wheel's infeeding into the blank with an allowance for the error of the shape of the machined surface;

—stabilization of the force parameter during the rough and finishing stages of machining;

—diagnosis of the cutting power of the grinding wheel and determination of the moment of the correction;

—more rational distribution of the allowance between individual stages in the cycle.

To further increase the efficiency of using active monitoring instruments, the OKB SA is currently developing instruments with program implementation of control algorithms based on microprocessors. Using microprocessor technology will make it possible to expand the functional capabilities of active monitoring instruments in the area of improving the diagnosis of and optimizing the grinding process, diagnosing the precision of active monitoring instruments, statistical monitoring, and gaining the capability of bringing the resultant information to a higher level.

UDC 621.924.6-503.57:621.833.052

Adaptive Control System for Gear-Grinding Machines

907F0080W Moscow MASHINOSTROITEL in Russian No 10, Oct 89 pp 21-22

[Article by R. Z. Khaykin]

[Text] In small- and medium-series production, the real efficiency of using automaton machine tools and semiautomatic machine tools frequently turns out to be

below the rated efficiency guaranteed by the manufacturer. This is especially characteristic for grinding gears and is related to the problem of fully allowing for destabilizing factors (the imprecision of the alignment of the machine tools, erroneous tool selection, fluctuations in the blanks' allowances, etc.) and the absence of active monitoring instruments. In view of this, the OKB SA, working jointly with the Moscow Grinding Machine Plant, developed an adaptive control system for the model MSh-375 NC semiautomatic gear-grinding machine.

The adaptive numeric control system includes a multiprocessor control device, and besides servo drives, it also contains active monitoring instruments and several other measuring devices and servo mechanisms. Before a batch of gears is machined, the adjuster sends (in an interactive mode) the system data about the product (its geometry, allowances, modification of the teeth) stipulated by the sketch and, under control of the system, implements the adjustment of the machine tool's nodes that have been calculated by the system.

When the first workpiece of a batch is machined, the system refines those characteristics of the process that it has and then corrects them as they change. The blank is measured by active monitoring instruments both before and during the machining, which results in a flexible automatic change of the control tactics: the number and types of passes, the cutting modes, the frequency of correction, etc. The measuring instruments are also adjusted automatically. Provision is made to develop a diagnosis of failures. Thanks to this, servicing a malfunctioning machine (independently of the duration of the fulfillment of an order to manufacture a batch of gears) is reduced to loading and unloading blanks and replacing (when the system requires it) worn grinding wheels.

By using a video terminal the operator can correct the length of the common normal, profile, direction, and modification of the teeth depending on the results of external acceptance inspection. To eliminate subjective errors and reduce the amount of time for monitoring, the system has the capability of combining groups of machine tools with a stationary shop NC tooth-measuring module connected with the machine tools being serviced by an information channel. From a functional standpoint, this structure is a complete system for finishing machining of precision gears that simultaneously performs acceptance inspection of different types of gears with documentation and transfer of the manufacturing corrections to the adaptive NC control system.

Tests of the adaptive NC control system showed that it provides (without intervention by service personnel) stable production of gears with deviations less than 3rd degree tolerances (GOST 1643-81). The machining productivity is about twice that on the same machine tool without the adaptive NC control system (the productivity is automatically increased as the precision requirements decrease). In addition, the system does not require programming during operation and has definite capability for self-instruction.

UDC 621.865.8.004.14;658.527.011.56;621.941.1.077

Robotized Line for Machining Conveyor Roller Axles

18610424a Moscow MASHINOSTROITEL in Russian No 1, Jan 89 p 14

[Article by Engineers S.G. Stepanov and G.T. Boyko]

[Text] PO [production association] "Donetskgormash" implemented a robotized line (RL) for machining belt conveyor roller axles. A roller is made of a rolled bar blank, 34 mm in diameter and 493 mm long. The RL consists of a mechanism that feeds blanks to the loading point of the transfer system, pallet-type automated transfer system type KR-20, industrial gantry robots "Pirin", semiautomatic centering mill model MR-71M, semiautomatic copying lathe model EM-473-1 and ancillary equipment.

The RL can perform the following technological operations: mill both end faces of a part, drill center holes, machine axle journals, face end faces and shoulders and cut grooves. Robots load blanks into metalcutting equipment, remove machined parts from machine tools and feed parts and blanks from the transfer system to machine tools and back to the transfer system.

The experience in operating the RL demonstrated high reliability of the robots and the transfer system compared to the semiautomatic copying lathes. For instance, the share of RL downtime due to breakdowns and repairs of robots and the transfer system is equal to 9 percentof total downtime, while for copying lathes it is equal to 40 percent.

The need to improve the reliability of machine tools determined the direction of plant professionals' work aimed at their modernization. They achieved a number of technological advantages by changing the program of robot movement over the centering mill. Now, a blank is placed for this operation against a stop at one end. This made it possible to reduce the length allowance by 50 percent and only face one end.

The arrangement for locating a blank for turning was also modified. The fixed center of the tailstock quill was replaced with a floating one. This led to a number of improvements in robot and lathe electric diagrams. As a result, the accuracy of axle machining has improved.

The addition of a time relay, which controls the lower position of the copying carriage slide, was an important aspect of modernization of lathes model EM-473-1. This ensures that at constant speed and travel time the slide accurately reaches the specified machining starting point. At the same time, the sequence of operations of the copying and cross carriages is strictly observed - the cross carriage feed is turned on only after axle journals have been machined. This technical solution sharply reduces the probability of breakage of grooving and straight-turning cutting tools.

The tool holder of the EM-473-1 copying carriage, where custom-designed cutting tools were previously installed, was replaced with a new design. This made it possible to use standard, more rigid straight-turning tools and as a result intensify cutting conditions and reduce cutting time by 30 .

The design of several subassemblies of the upper side of transfer system KR-20 was improved. This expanded its technical parameters, which made it possible to move longer parts. At the same time, the counter was added to the system, which considerably simplified the job of keeping track of parts machined on the RL.

The modernization of the robotic line made it possible to increase its annual capacity by 20,000 axles above the rated capacity, ensure a steady quality of machined parts and increase the reliability of its metal-cutting equipment.

UDC 621.924.93

Trimming and Finishing of Parts With Intricate Contours

18610424b Moscow MASHINOSTROITEL in Russian No 1, Jan 89 p 25

[Article by Candidates of Technical Sciences L.A. Eizner and A.S. Murakhver and Engineer B.F. Pervushin]

[Text] At present, trimming, finishing and hardening take as much as 20 percent of piece-part time. Trimming and finishing of small parts with intricate contours, such as handles, knobs, latches, etc., are especially difficult.

For many years, the Section of Trimming and Finishing Methods of the NTO [S&T Society] of the Gomel Design Planning and Experimental Institute of Retooling and Preparation of Production in cooperation with the Gomel Polytechnical Institute have been working on studying and implementing abrasive-jet treatment.

The unit (Figure 1) consists of drum 1 with perforated walls, into which parts are loaded. Drum rotation is provided by a DC motor via gearbox 2 and a V-belt drive 3. Parts rotate with a drum around their centers of gravity and gradually pass through the action zone of a hydroabrasive jet, which comes out of a jet-abrasive gun that provides double acceleration of suspension. Spent suspension drains into preparation tank 4 through the holes in the drum walls, and pump 5 feeds it back to the gun. This is a continuous process.

Parts are trimmed and finished by the hydroabrasive jet in a rotating drum due to their friction against each other in the mixture with abrasive granules and the action of the jet of abrasive particles ejected from the gun.

The most intensive treatment occurs when parts are passing through jet action zone A (Figure 2). Its size can be computed using from the following formula:

$$S = \frac{\pi \left(L + \frac{D}{2\,\mathrm{tg}\,\beta}\right)^2 \mathrm{tg}^2\beta}{\sin\alpha\,(1 - \mathrm{tg}^2\beta/\mathrm{tg}^2\alpha)^{3/2}},$$

where S is the zone area, mm2; L is the length of the hydroabrasive jet, mm; D is the nozzle diameter of the jet-abrasive gun, mm, and α and β are the spray-cone angle and angle of incidence of the hydroabrasive jet, respectively.

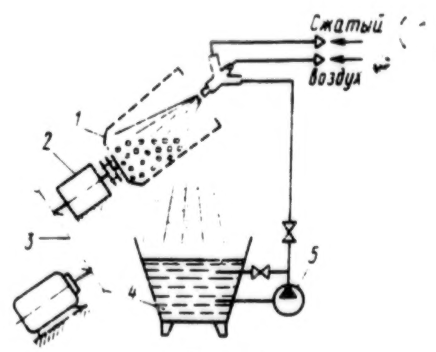


Figure 1

Key: 1. Compressed air

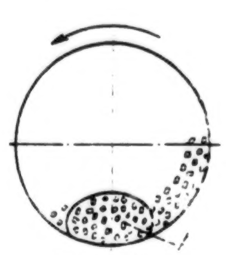


Figure 2

The frequency with which parts enter the jet action zone depends on the rotational speed of the drum. At a low rotational speed, parts turnover in the jet action zone is slow, and at a high rotational speed it is too fast.

The optimal speed was determined in a series of experiments.

It has been established that the maximum frequency at which parts enter the jet action zone is achieved at 15-20 RPM.

These experiments made it possible to develop a jet-abrasive module. The module makes it possible to perform trimming and finishing of small parts with intricate contours, made of any type of structural materials, in an automatic mode.

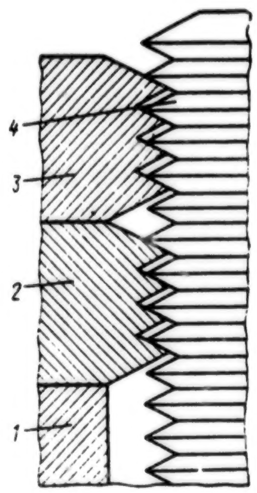
UDC 621.924.93

Method for Increasing Strength of Threaded Joints

18610424c Moscow MASHINOSTROITEL in Russian No 1, Jan 89 p 25

[Article by Engineer A.P. Kostin]

[Text] A new method for increasing the strength of threaded joints by more evenly distributing the load among thread turns in a composite nut, which is made using a new method for assembling threaded joints, is proposed (USSR Certificate of Authorship 1321955).



Two nuts 2 and 3 are screwed onto threaded rod 4 (a bolt or a stud). Nut 2 is screwed on to part 1 to be tightened and is tightened by hand using a small force. This step takes up clearances in the threaded joint - between the face of nut 2 and the surface of part 1 and between thread turns of nut 2 and the threaded rod. Then, to take up clearances in the threaded joint, nut 3 brought to the face of nut 2 and tightened by hand using the same small force.

Using a scriber or electrograph, a common mark is made on mating outside surfaces of the nuts along the axis of the threaded joint. Then, one holds nut 2 from turning and screws on nut 3 by angle $\gamma = 5\text{-}10\,°$. This increases the boundary thread pitch by ΔS. Using low-penetration welding and observing other conditions for reducing welding deformations, the nuts are joined permanently. Then, the two nuts are turned together to tighten the threaded joint to the work load. As a result, the load is distributed more evenly than in a solid nut of the same height. The proposed method improves the stability of tightening, as well as the strength, reliability, service life and other properties of machines and structures.

UDC 621.791.3.03;621.951.4.002.2

Gun Drill Brazing Device

18610424d Moscow MASHINOSTROITEL in Russian No 1, Jan 89 pp 46-47

[Article by Engineers A.Y. Voronin and A.I. Kosikh and Doctor of Technical Sciences A.K. Khersonskiy]

[Text] The use of gun drills with monolithic hard alloy heads for drilling deep holes is increasing.

A profiled hollow rod 2 (Figure 1) with a V-groove for removing chips and shank 3 are brazed to the working portion (head) 1, which has holes for feeding LC [lubricant-coolant].

Brazing quality and accuracy specifications are very strict, because head-rod misalignment increases grinding allowance of the OD and front surface of the head and causes a shift and partial overlapping of LC holes and wall thinning in the LC holes area, which reduces the strength of the head and the entire assembly. The asymmetry of the brazed seam and the absence of joint thickness specifications, as well as discontinuities and low penetration increase internal stresses in the hard alloy and reduce the joint strength.

NPO [scientific production association] "Tekhnolog" developed a device that ensures alignment of the gun drill head with the rod during assembly and brazing. The device has been implemented at a number of tractor and agricultural machine building plants. Its design ensures mutual orientation and alignment and of the gun drill head and the rod, moving the head and the rod towards each other and axially compressing them with adjustable force P during brazing, and blowing of head galleries and the rod groove.

The device (Figure 2) consists of base 1 with guide posts 2 equipped with antifriction bushings 3. Posts 4 with locating cams 14 and 15 (section A-A) and stops 13 are installed on the guide posts. The cams are water-cooled and can be adjusted along axes X and Y; the stops are adjustable along axis Z. Air cylinders 6 with piston rods 12 are installed on brackets 5 attached to the posts. Air cylinder 11 connects posts 5. Induction coil 8 connected to the secondary circuit of the induction hardening unit model LZ-107V is installed between the posts.

Before the work begins, positions of the locating cams and stops are adjusted using a control mandrel (standard), to ensure the alignment of head 7 and rod 9. A drill head is placed onto locating surfaces of the cams. Then, the air cylinder on the left post is turned on. Its rod applies force to one of the head shoulders, turns the head until it touches the locating surface of the stop, and locks it in this position. The drill rod is locked the same way.

The head and the rod, which are now rigidly fixed in the radial direction, can move independently in the axial direction, from the specified clearance between them to full contact, while maintaining the alignment. After the

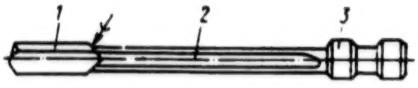


Figure 1

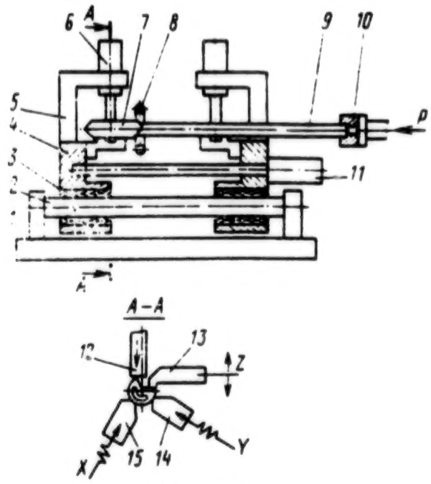


Figure 2

parts have been positioned and locked, a braze preform is placed between the head and the rod, and they are compressed together with the help of air cylinder 11. Then, high-frequency heating is turned on, to braze the joint in accordance with standard parametrs of brazing hard alloy to steel. For uniform heating, the joint is given limited oscillating motion inside the induction coil along antifriction bushings 3.

After the heating is turned off, the drill is blown with compressed air through nozzle 10. Then, air to all air cylinders is shut off, the drill is released and placed in an oven, to relieve stress at (300 +/- 15) °C.

The device makes it possible to mechanize the assembly process and stabilize technological parameters of brazing and thus increase the output and improve the quality of gun drill brazing.

These devices are used at the Kirovograd plant "Gidrosila" imeni the 25th CPSU Congress, Cheboksar Industrial Tractor Plant and Melitopol Tractor Hydraulic Unit Plant imeni the 25th CPSU Congress in series production of gun drills 8.1, 8.9, 9.6, 12.1, 10.3, 13.3, and 16 mm in diameter. The misalignment tolerance is under 0.1 mm.

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